THE RECONSTRUCTION AND TESTING OF SUBSISTENCE AND SETTLEMENT STRATEGIES FOR THE PLAINS, PARKLAND AND SOUTHERN BOREAL FOREST

BY

MARY EVELYN MALAINEY

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree of

DOCTOR OF PHILOSOPHY

Department of Anthropology
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THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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ABSTRACT

Existing subsistence-settlement patterns proposed for the late Precontact inhabitants of Western Canada assume the parkland was the focus of bison and hunter-gatherer winter activity. This is not supported by information in historic accounts and the archaeological record. Instead, it is proposed that plains-adapted groups regularly remained far out in the grasslands where the concentration of wintering bison was highest. By switching from fat-depleted adults to foetal and newborn bison in late winter/early spring, plains-adapted peoples did not need to use fish and avoided possible deleterious physical effects associated with this change in diet. Parkland- and forest-adapted peoples moved to the northern edge of the grasslands to exploit transient herds on the margins of the wintering range. The diet of parkland- and forest-adapted peoples was more diverse and included the use of spawning fish in spring.

These hypotheses are tested using materials from eighteen grassland, transition zone, parkland and forest sites. Gas chromatographic analysis of over 200 residues extracted from cooking pots recovered from these sites is consistent with the faunal and tool recoveries. Wintering sites in the grassland contain mainly cooking pot residues identified as from large herbivores alone or in combination with plants, foetal bison bone and tools associated with a hunting economy. The former inhabitants of transition zone sites also followed a hunting economy in the winter and early spring, but traces of fish use are evident in the tool kits, faunal assemblages and vessel residues. Evidence of the use of fish, in the form of harpoons, fish remains and vessel residues, increases in parkland sites, but is highest in forest sites where it is a major source of food.

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ATP	adenosine triphosphate
°C	degrees Celsius
Cx:ywz	shorthand designation for a fatty acid consisting of a chain length of x carbon atoms with y double bonds with the most distal double bond on the zth carbon from the methyl end of the chain.
d_{ij}	Euclidean distance coefficient
E	extremely high, ≥50%
g	gram
GC	gas chromatography
GC/MS	gas chromatography with mass spectroscopy
GLC	gas liquid chromatography
H	high, 26.00-37.00%
I.D.	internal diameter
L	low, 3.00-7.99%
ml	millilitre
m	metre
M	medium, 8.00-14.99%
MH	medium high, 15.00-25.99%
MNI	minimum number of individuals
N	normal concentration
NMR	nuclear magnetic resonance spectroscopy
%S	percentage of saturated fatty acids
PRINx	the xth principal component score
RMS	root-mean-square
r	correlation coefficient
TMS	trimethylsilyl
tr	trace, 0.00-2.99%
VH	very high, 38.00-49.99%
VLCP	very long chain polyunsaturated fatty acids
VLCS	very long chain saturated fatty acids
WCOT	wall-coated open tubular
µl	microlitre

Chapter 1. Introduction

This study represents an attempt to reconcile the information in historical, archaeological and ethnographic records with settlement and subsistence strategies for the Precontact inhabitants of Western Canada. Decisions regarding winter site selection and resource exploitation are considered with respect to dietary preference and the overall utility of food items. The rational of fish avoidance is also considered. The proposed settlement and subsistence strategies are tested against archaeological recoveries from several Late Precontact Period sites in Western Canada. Faunal and tool assemblages are considered as well as the identified residues of cooking pots recovered from these sites. Fatty acid components of absorbed residues were extracted from the vessels and analyzed using gas chromatography. The fatty acid compositions of the archaeological vessels were compared to decomposed experimental cooking residues to identify their former contents.

As discussed in chapter 2, reconstructions of the settlement and subsistence activities of the Precontact inhabitants of Western Canada are strongly connected to the perceived movement and physical condition of bison. Fundamental to most existing proposals is the assumption that the majority of bison sought shelter in the parkland during winter. In turn, Precontact hunter-gatherers from the Northern Plains and southern boreal forest were drawn to the parkland where food, shelter and fuel for fires were abundant. In late winter and early spring, when bison were fat-depleted and moving onto the open grasslands, other food sources, such as seasonally abundant spawning fish, were exploited. Descriptions of vegetation recorded by earlier traders agree with those of the nineteenth-century Palliser and Hind expeditions in that the distribution of the parkland was

considerably narrower and located north of its current location (Hind 1971). When the existing hypothesized patterns of bison and human movement are compared to the early Postcontact vegetation zones, a number of inconsistencies arise.

Information regarding the movement of bison and humans from historic records is presented in detail in chapter 3. Contrary to expectations, the majority of both bison and human hunter-gatherers appear to have remained on the plains throughout the winter. Each year, the fur traders who wintered at posts constructed in the parkland sent hunters out to the plains because the bison did not approach the establishments. Herds of wintering bison and the camps of mobile hunter-gatherers were generally not encountered until the northern edge of the grasslands was reached. Vast numbers of bison were observed far out on the plains where large Native winter camps were established. Traders witnessed communal bison jumps involving hundreds of people operating on the open grasslands in the middle of winter. Bison hunting continued throughout the late winter and early spring. Although lean adult bison were not valued as food, the pregnant females were hunted for the foetal bison they were carrying and newborns were taken for food. Archaeological evidence from the study area appears to support the historic accounts. Numerous sites on the plains contain foetal bison remains, while the tool and faunal assemblages attest to a singular bison hunting economy. Archaeological evidence for the use of fish seems restricted to sites in the transition zone, parkland and forest.

In chapter 4, the factors affecting the subsistence and settlement choices of Late Precontact Period hunter-gatherers are considered; in particular, native dietary preferences are reviewed. Evidence that people adapted to a diet of lean meat may have difficulty

using fish as food is provided. This consists of historic accounts of the sudden switch in diet from bison to fish producing deleterious physical effects. The symptoms recorded resemble steatorrhea and diarrhea resulting from lipid malabsorption. People with more varied diets, such as those adapted to life in the parkland and forest, were probably better able to make the dietary transition from bison to fish without suffering severe consequences.

Newly hypothesized adaptive strategies for the Late Precontact Period inhabitants of the plains, parkland and southern boreal forest are presented in Chapter 5. The subsistence and settlement strategy proposed for plains-adapted peoples is unique in terms of the heavy reliance on bison throughout the year. Ensuring access to numbers of wintering bison high enough to facilitate communal hunting was the primary goal. The highest concentration of these animals was observed on the grasslands of southern Alberta and southwest Saskatchewan. The winter grazing conditions in this region are favourable because warm Chinook winds restrict snow accumulations on the plains. By shifting their focus from adults to foetal and young animals, the need to use either lean meat or fish for food was avoided. Plains-adapted peoples found shelter by forming their camps in river valleys; in the absence of wood, bison chips provided fuel for fires.

The subsistence and settlement strategies proposed for parkland- and forest-adapted peoples are similar in that bison procurement is more opportunistic. Groups taking advantage of the bison herds formed their camps on the margins of the wintering range. In an average winter, camps could be formed in aspen groves on the northern edge of the grassland, which provided shelter and wood for fuel. In a mild winter when bison

remained far out in the open grasslands, these groups would either exploit different resources, such as deer, elk and moose, or move deeper into the plains. When bison moved south in late winter and early spring, a variety of other food resources, including spawning fish, were exploited.

Information from eighteen late Precontact archaeological sites was used to test the proposed settlement-subsistence strategies. In particular, the location and subsistence strategies evident at sites occupied during the winter and spring were considered. The economy of the site inhabitants was established using extant analyses of the tools, faunal assemblages and any available palaeobotanical studies. The gas chromatographic analysis of the lipid component of cooking residues extracted from over 200 late Precontact vessels from these sites provided an innovative and important source of information.

A reference collection of more than 130 plant and animal foods was established and fatty acid compositions of the different foods were determined for comparative purposes. In order to assess the effects of thermal and oxidative decomposition, experimental cooking residues were prepared and allowed to decompose for different lengths of time prior to analysis. The fatty acid composition of modern foods and, most importantly, the patterns of decomposition observed in the experimental residues formed the basis for the identification of archaeological vessel residues. An overview of vessel residue analysis, lipids and gas chromatography is presented in chapter 6, the experimental procedures followed in this study appear in chapter 7. The results of the analyses are presented in chapter 8; interpretations are given in chapter 9.

Finally, the proposed settlement-subsistence strategies were evaluated with respect

to the archaeological and analytical data. The value of vessel residue analysis using gas chromatography to address archaeological problems is considered.

Chapter 2. Subsistence-Settlement and Vegetation Boundaries

Archaeologists agree that the seasonal movement of bison would have a determining effect on the settlement pattern of those hunter-gatherers who strongly depended on them. There is also a consensus that the majority of plains bison regularly moved into the parkland during the coldest months of winter. The presence of these bison would attract people who also spent the winter in the sheltered parklands. The Northern Plains are considered to have been uninhabitable in winter due to the severe weather and shortage of wood for shelter and fires. This perception is, however, inconsistent with historic accounts which clearly describe vast, stable herds of bison wintering on the Northern Plains. The early historic record includes locations of winter camps of plains, parkland and forest-adapted peoples on the Northern Plains, close to reliable bison populations. This pattern is consistent with that observed in the archaeological record; there are several examples of large winter sites with dense artifact concentrations in the grasslands.

It is necessary to adjust our perception of the northern grasslands as a desolate, uninhabited environment in winter. The wintering sites of plains-adapted people were located far out on the open plains. The winter camps of parkland and forest-adapted people were situated closer to the northern grassland edge.

2.1 Current Thinking about Bison Ecology and Settlement Subsistence Systems

Historic records, ecological factors and modern analogies are used to gain insights into the wintering behaviour of free-ranging bison in Precontact and early Postcontact times. Movements of bison are central to the reconstruction of the seasonal activity

patterns of those who depended upon them. While Moodie and Ray (1976) were not the first to examine bison movement, the conclusions which arose from their work are reflected in the basic assumptions of later models.

Using mainly mid-nineteenth-century Hudson Bay Company records and the writings of missionaries in the area, the researchers found "fundamental zonal regularities" in bison movement. Moodie and Ray (1976:46) suggest that:

> In the case of the Canadian Plains, it is readily apparent from the historical evidence that the buffalo sheltered in the wooded areas in the coldest months of winter and, from spring until early winter, grazed on the open grassland. At the regional level, this involved a generally northward movement into the parkland belt in winter, and, in spring, a southerly exodus into the open prairie.

Bison were most numerous in the northern parklands from December through March although factors, such as winter temperatures, snow conditions, hunting pressures and the destruction of vegetation by fires or grasshoppers, affected regional movement (Moodie and Ray 1976:48-49). The influence of these factors led to local and temporal variation; however, the people who depended on bison understood their effects so the resulting impact on herd movement was predictable.

In some cases, however, mild weather affected bison movement so dramatically that groups were unable to successfully adjust their hunting strategies. As discussed by Clow (1995), the Brulé and Yankton of south-central South Dakota faced starvation in the winter of 1832-33 because bison did not move towards the Missouri River, where their winter camps were established. The bison remained close to interior plains, beyond the regular hunting range of the Brulé and Yankton, eventually forcing the groups to split and

travel long distances to the north and south in search of wintering bison (Clow 1995:265-266).

Other studies of bison movement by Morgan (1979,1980) and Gordon (1979) suggest the behaviour of the bison rested heavily on ecological factors. The availability of superior forage is regarded as the major stimulus for the pronounced movement patterns. In general, herds moved from their summer range in the central grasslands to the arching winter range up to and including the outer periphery of the Aspen Grove region (Morgan 1980:157). The majority of herds spent the summer and early fall in the Xeric Mixed Prairie. Major concentrations of bison were expected in their winter range, the Fescue Prairie of the Aspen Grove Region and the transitional grasslands of the Aspen Grove Region and river valley complexes, during the late fall, winter and spring. Morgan (1979:129-133) predicted that the associated Fescue Prairie grasslands of the sheltered Aspen Grove region, Valley Complexes and Uplands would be the only areas able to accommodate high density sedentary herds during the winter.

More recently, Epp (1988:314-315) suggested a dual dispersion strategy for plains bison. He proposed that small, sedentary herds of bison could have remained on the grasslands throughout the year, "near water in wooded, anomalous, frequently topographically more abrupt landscapes, such as river valleys, ranges of hills and sandhills, but often feeding in grassy uplands nearby" (Epp 1988:314-315). He is, however, in agreement with the afore mentioned researchers that the majority of bison moved into the main woodlands in winter. Epp (1988:315) even suggests that "the *overall concentration of animals* in the woodlands during the winter would exceed that on the open plains in

summer (and, certainly, in the winter), *because the woodlands were smaller in area.*"

While there are variations in the proposed patterns of bison movement, these scholars are unanimous in their assertion that the majority of plains bison wintered in the sheltered aspen parkland. This consensus extends to many of those who have proposed hunter-gatherer settlement-subsistence patterns for the study area. Ray (1974:27-50) argued that prior to and during the fur trade era, plains- and forest- dwelling Assiniboin and forest-dwelling Cree were drawn to the parkland in winter. Those who inhabited the plains and woodland had access to relatively abundant food resources from spring to early summer and again during late summer and autumn. From December to February, however, little food was available and the inhabitants would have been faced with threats of starvation. The parkland resources were regarded to be plentiful in winter because both bison and shelter were available (Ray 1974:32).

Syms (1977) reached similar conclusions on the basis of seasonal changes in the availability and abundance of plant and animal resources of the different vegetation zones. He (1977:32) suggested that the resource potential of the grasslands dropped dramatically in the fall "as the vast bison herds migrated towards the Aspen Parkland where they broke up into smaller herds. Sheltered river valleys and uplands supported localized herds, but the majority of the animals left the zone." The aspen parkland was considered to have a higher resource potential than either the grassland or the southern boreal forest during the autumn, winter and spring (Syms 1977:30-32, Figure 7). This pattern was reflected in the subsistence-settlement patterns of groups whose core areas were forest or aspen parkland (Western Cree, Western Ojibwa, Assiniboin, Yanktonai, Plains Ojibwa, Plains Cree,

Ottawa and Santee), as well as the grassland (Teton and Gros Ventre). All of these mobile hunter-gatherers were considered to have wintered in the aspen parkland (Syms 1977:40,Table 4).

Nicholson (1988:356) and Smith (1988:17) agree with Syms (1977) on the point that the plains were occupied only in warmer months. Nicholson (1988:354) suggests that bison were a primary resource in the parklands during the spring, fall and winter and a secondary resource in the summer. Smith (1988:19) suggests that the bison's loss of fat and increasing unpredictability of movement made pounding activities impractical after January. Afterwards, tribal level gatherings of people were forced to rely on stores of dried and frozen meat for the remainder of the winter.

Meyer and Epp (1990) suggest that archaeological evidence from central Saskatchewan indicates that the parkland was occupied by plains bison hunting groups in the winter and that culture contact between plains and forest groups was limited to interaction on the southern edge of the boreal forest. They (1990:338) conclude that plains bison hunters dominated the parkland and may have prevented boreal forest groups from utilizing it.

These scholars agree that both forest and plains-adapted hunter-gatherers were attracted to the sheltered aspen parkland during winter. They consider that, during an average winter, the open plains were such an inhospitable environment that both humans and most bison would abandon the exposed grassland in favour of more wooded areas, such as the parkland, until spring (Ray 1974:31-33; Syms 1977:53; Morgan 1980:156; Gordon 1979:37; Epp 1988:316; Meyer and Epp 1990:321-323; Smith 1988:18).

> Under average or severe winter conditions the bison scattered in search of shelter. Other game responded in similar fashion since they could not survive on the open grasslands in the face of chilling winter winds. At these times it would have been difficult for any Indians to remain in that environment, and there is little evidence that many did (Ray 1974:32).

> During the winter the bison herds sought shelter and sustenance in the aspen parkland. This area remained their winter range unless ameliorating weather permitted temporary occupation of the high carrying-capacity Fescue Prairie (Gordon 1979:37).

> Cold temperatures, driving winds, sudden blizzards and a complete lack of shelter make [Alberta prairie upland] locales hazardous in the extreme (Vickers 1991:58).

Smith (1988:20) argues that bison began to move out of the wooded parkland in mid-February and suggests that by early March pounding activities would be impossible because herd movements were increasingly erratic. "Yet, for people to venture out in search of bison in large groups could be devastating because spring weather was so unpredictable" (Smith 1988:20).

Some archaeologists in Alberta rely heavily on the works of Ewers (1955; 1958), in particular on the Blackfoot seasonal settlement pattern, when interpreting archaeological sites.

> Through the dead of winter the Blackfoot bands pitched their lodges among the trees in sheltered valleys offering maximum protection from winds and snow. It would have been suicidal for them to have remained in open country for extended periods at that treacherous season (Ewers 1958:14).

Although several post-cranial foetal bison elements were recovered from the Ramillies site, Brumley (1976:23) considers a late winter-early spring occupation of the site unlikely:

> Historic and ethnographic sources indicate Plains groups selected wooded areas for winter camp locales. Game naturally congregated in these areas and wood for fuel and shelter were also available. Ramillies is situated a considerable distance from any such locale decreasing the likelihood of a winter-early spring occupation.

Vickers (1991:62) regards encampments around Calgary to be unsuitable for winter occupation due to a lack of firewood and shelter.

This image of the plains as dangerous, empty and uninhabitable, however, is not supported by historic records.

2.2 The Vegetation Boundaries in the Late Precontact Period

Fundamental to the understanding of bison movement and Precontact human settlement and subsistence patterns is an appreciation of the distribution of the pre-agricultural vegetation zones. A perusal of the literature reveals that almost every author depicts the limits of the parkland belt differently. Some assume that contemporary depictions of vegetation zonation can serve as approximations of the Late Precontact and Early Postcontact Periods while others rely on environmental reconstructions. The demise of bison herds and the introduction of European settlements in the late 1800s brought a complex set of environmental factors into play. The effects of bison grazing and prairie fires were reduced or eliminated, causing the parkland belt to extend southward (Bird 1961:ix). Conversely, the end of the Little Ice Age in the 1850s may have instigated a northward zonal movement while clearing activities associated with the introduction of agriculture may have caused the southern margin of the parkland to recede. Attempts to reconcile these conflicting influences have resulted in a myriad of modern interpretations (Smith 1988:15; Ray 1974:28; Morgan 1980:146; Syms 1977:17; Meyer and Epp

1990:322).

Instead of offering yet another modern interpretation, the first-hand observations of Europeans who made trips into the region during the late eighteenth- and early nineteenth-century are considered. Characteristics of the vegetation recorded in the journals of Anthony Henday, Matthew Cocking, Alexander Henry the Elder and the Younger, Peter Fidler, Daniel Harmon and others are presented in Table 1. Modern place names referred to in the table are illustrated in Figure 1; the locations of fur trade era posts are provided in Figure 2. These records show the boundaries of the forest and, to a greater degree, the grasslands were well north of their present location, resulting in a parkland belt narrower than that presented on most modern maps. The country west of Dauphin Lake, between Swan River Fort and Bird Mountain, as well as much of that along the Carrot River was open. The forest edge corresponded to the Saskatchewan River from Nipawin to the forks, then it followed the north branch a short distance. There were extensive grasslands in the vicinity of Edmonton House, Fort George, and in the region between Bird Mountain and Fort Alexandria. The edge of the grasslands was encountered west of the Red River in southeast Manitoba, and near Montagne á la Bosse and the Souris River forts in southwest Manitoba. It was located north of Good Spirit Lake in southeast Saskatchewan; it was found just west of modern Humboldt and at the elbow of the North Saskatchewan River in central Saskatchewan. The country around the Eagle and Bear Hills of southwest Saskatchewan was described as barren ground. Trees were encountered only after ten days journey north of Chesterfield House to Edmonton House; the closest trees to Chesterfield House were four days journey to the south. The

Table 1. Descriptions of vegetation in historic accounts, showing the extent of the plains, parkland and forest.

Year	OBSERVER	AREA	DESCRIPTION
1795	M'Gillivray (1929:77)	Edmonton House	posts were constructed at the "termination of an extensive plain"
1795	Fidler (MacGregor 1966:103)	Edmonton House	not considered to be a suitable place to build due to the scarcity of timber
1794	M'Gillivray (1929:33)	Fort George	"The Plains arround us are all on fire...We are almost suffocated with smoke..."
1754	Henday (Russell 1991:95)	modern Red Deer	the camp he visited was on the "Muscoty" or buffalo grass plains.
1792	Fidler (MacGregor 1966:66)	modern Red Deer	at the east of edge of wooded country; thin woods gave way to bare plains which extended for several hundreds of miles towards the south east
1800	Fidler (1967:268)	Chesterfield House	"The Woods here few and bad for building with"; likely restricted to river bottoms (MacGregor 1966)
1801	Fidler (1967:283)	betw Edmonton and Chesterfield Houses	"The men say that for 10 days not a single stick is to be found, being entire barren plains"
1801	Fidler (1967:302 , 309)	SE corner of modern Alberta	the nearest pine trees are 70-80 miles away, southwards of the Bad River; a journey of about four days
1772	Cocking (1908:102)	SW of Fort à la Corne (Morton 1973:284)	"Country hilly, producing short grass, low willows & ponds in places; also many vermin holes."
1772	Cocking (1908:103-104)	north of Batoche (Morton 1973:284)	"Travelling through a hilly, short grass country: A few small sticks & ponds in places; but mostly small."
1754	Henday (1973:24)	elbow of the North Saskatchewan River	"Level land, no woods but what grows on the banks; plenty of berries."
1754	Henday (1973:24)	modern Battleford, SK	"Level Barren land, not one stick of wood to be seen, & and no water to drink."
1772	Cocking (1908:105-106)	Eagle and Bear Hills	tent poles collected along Eagle Hills Creek otherwise "Country barren, & and barren hillocks..."
1772	Cocking (1908:106-108)	near Ruthilda & Biggar, SK (Russell 1991:107)	bareness of the county noted; only a few stands of poplar were encountered during several weeks of travel

1794	M'Gillivray (1929:22) (also Fidler (MacGregor 1966:18) and Henry the Younger (1992:351))	just south of the forks of the North and South Saskatchewan Rivers	"The face of the Country here assumes a different appearance, hither to our way was obstructed by thick woods, on each side of the River but now extensive plains interspersed with only a few tufts of wood, open themselves to view, and extend to the utmost extremity of your sight...."
1776	Henry the Elder (1969:269)	travelling southwest of Cumberland House	the country soon betrayed the characteristic openness of the plains, the wood dwindled away in both size and quantity
1776	Henry the Elder (1969:270-271)	former house of Finlay (near modern Nipawin)	now on the edge of the parkland
1776	Henry the Elder (1969:271)	between Finlay's House and Fort aux Trembles	country is now more open;"The only trees around us are starveling willows...We are now on the borders of the Plains."
1754	Henday (1973:20)	travelling along Carrot R. in east-central SK	in a few days the group entered a more open country with few bluffs of poplar and willows which gave way to treeless, level lands covered with short grass
1754	Henday (1973:21-22)	west of Humbolt, SK (Morton 1973:246)	the party were on the Muscoty, the buffalo grass plains, in a region of salt lakes
1776	Henry the Elder (1969:282)	from Fort aux Trembles to near modern Humbolt, SK (Bain 1969:285)	the country quickly became grassland with few bluffs of aspen; in two days "the country was one uninterrupted plain, in many parts of which no wood, nor even the smallest shrub was to be seen."
1800	Harmon (1957:35)	from Bird Mountain and Fort Alexandria	after crossing the Swan River "the country appears to be more hilly but almost destitute of Timber of any kind."
1800	Harmon (1957:35-36)	Fort Alexandria	the fort is built across the river "from a beautiful Plain about ten miles long"; just behind the fort are small groves of trees
1757 1759	Joseph Smith Joseph Waggoner	Good Spirit Lake (Russell 1991:112)	the lake was located on barren ground on the edge of the plains
1804	Harmon (1957:73-76)	from Good Spirit Lake to the Qu'Appelle R.	the country was an extensive plain;one could walk for a day without finding either wood or water
1804	Harmon (1957:77)	Qu'Appelle Valley	a little timber on the banks of the river, "but out in the Plain there is not Shrub to be seen."
1800	Harmon (1957:35)	betw Swan River Fort and Bird Mountain	on the second day they crossed a number of small plains; prior to reaching Bird Mountain, "The most of the day our walk has been over plains."

1769	W. Tomison (Russell 1991:114)	W of Dauphin Lake and N of Riding Mountain	grassy plains with ledges of small poplar and mostly barren ground
1804	Harmon (1957:84)	from Qu'Appelle River to Montagne á la Bosse	they left Fort Alexander and travelled three days to the Qu'Appelle then followed that river "always in a beautiful Plain" for two days to Montagne á la Bosse
1804	Harmon (1957:84)	Montagne á la Bosse	"the Country all around a level Plain."
1797	Henry the Younger (1988:203) (also Thompson 1985:97-99)	from the Souris River Forts to Ash House (modern Hartney)	travelled "through very hilly Country intirely destitute of wood"; there were thin woods along the Souris River but on either side "stretches out into the level plains. As far as the eye could reach, no wood to be seen in any direction."
1797	Thompson (1985:101)	Lauder Sandhills	while standing on some high sandhills he noted "No woods but a little along the River, and on the Turtle Hill."
1805	Harmon (1957:90)	Portage la Prairie	"Opposite the Fort there is a Plain as level as a House floor, which is about Sixty Miles long & one to ten broad"
1805	Harmon (1957:91) (supported by Henry the Younger 1988:23)	the forks of the Red and Assiniboine Rivers	"here abouts the Country appears to have a richer soil than any other place I have observed in this part of the world-and is covered with Oak, Basswood, Elm, Poplar and Burch &c. also here Red Plumbs & Grapes &c"
1800	Henry the Younger (1988:26)	betw the La Salle and Assiniboine Rivers	the land is marshy with thick growths of poplar and willow (1988:26).
1800	Henry the Younger (1988:26)	south of the La Salle River	plains covered with long grass "Stunted Poplars, Willows and Rose bushes was the only thing that I saw. No large wood to be seen excepting along the river."
1800	Henry the Younger (1988:32)	at the Riviére aux Gratias	west of the Red River was a continual level plain, "Not a tree or rising ground is to be met with to interupt the view, but on the east-side of the River the Woody Country Continues as below" (Henry 1988:32).

Figure 1. Map of the Northern Plains with modern geographic locations.

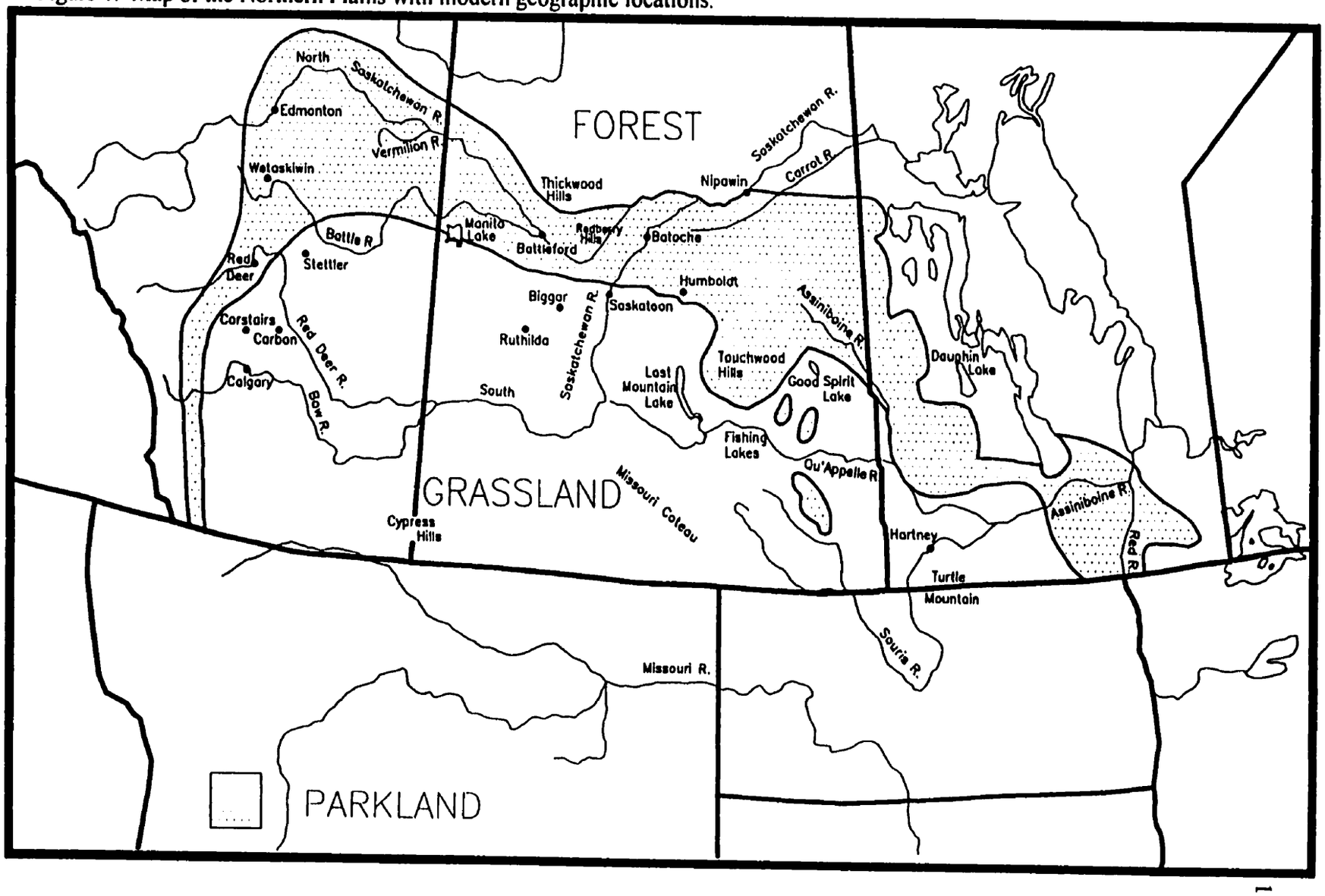
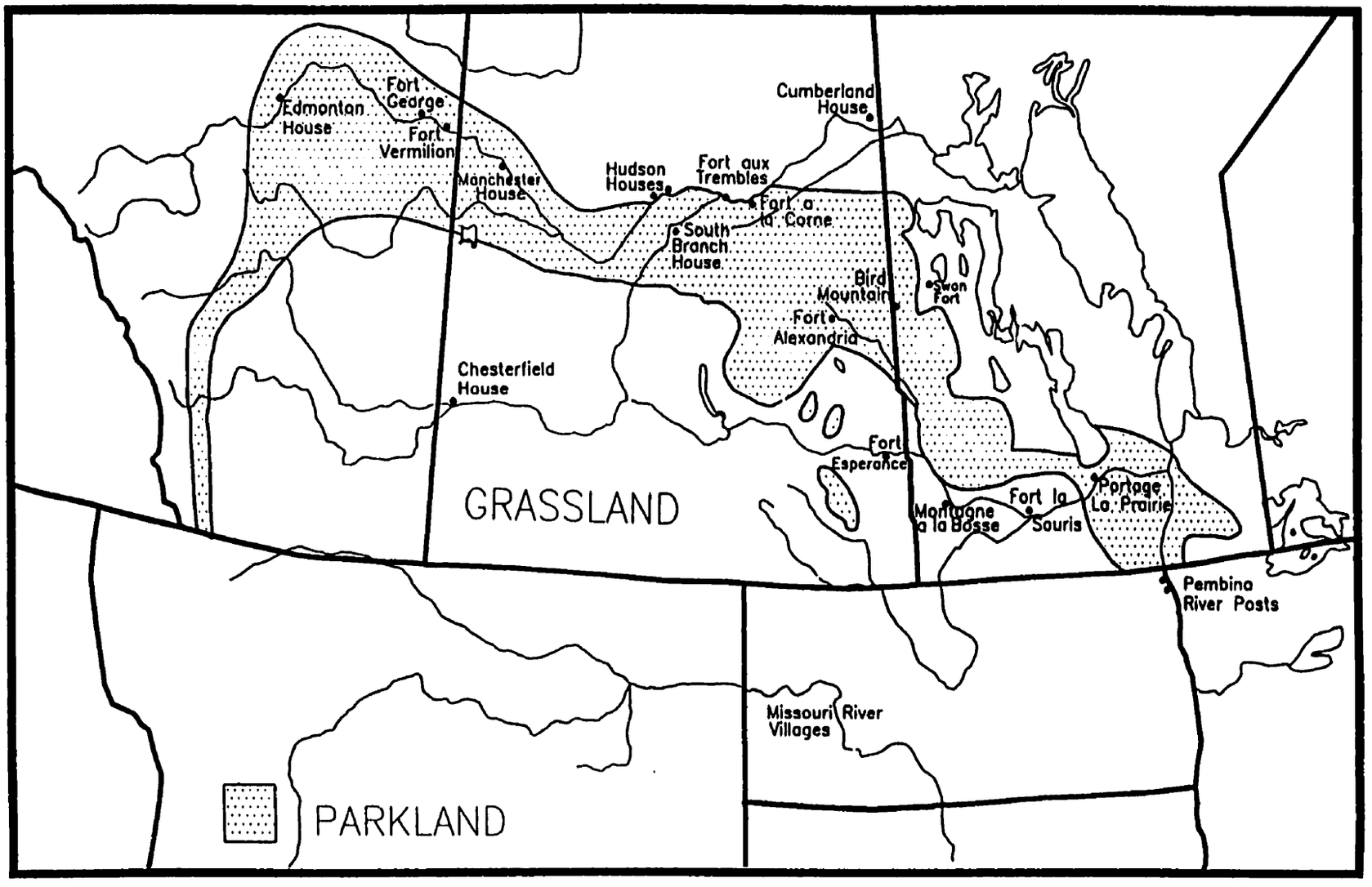


Figure 2. Map of the Northern Plains with fur trade post locations.



grasslands extended for hundreds of miles southeast of modern Red Deer.

In the late 1850s, Captain John Palliser and Henry Hind took part in government-sponsored expeditions to report on the physical features, nature of soil and timber, agricultural potential and presence of coal and other minerals in the area which today includes parts of British Columbia, Alberta, Saskatchewan and Manitoba (Palliser 1968a:3-5; Stubbs 1971:vi). As Spry (1968:cxiii) pointed out, "Settlers had to know whether, in the distant lands beyond Lake Superior, there was land north of the 49th parallel on which they could hope to build homes and make successful farms." The position of the vegetation boundaries offered by Captain John Palliser (1968a,b) and Henry Hind (1971) correspond to the first-hand observations of the Europeans who travelled through the area before them (Figs 1 and 2).

On the basis of his own observations from the Lake of the Woods to the forks of the Saskatchewan River and those of the Palliser expedition from the forks of the Saskatchewan River to the Rocky Mountains, Hind (1971 II:facing 223) published a map showing the vegetation of Western Canada in 1860. The map included a region of "arid plains" which corresponds well with the observed limits of the grassland and a "fertile belt" which corresponds to the observed extent of the parkland (Figs. 1 and 2). Palliser (1968a:9) described the arid plains as a "central desert" forming a triangle with its apex at 52° latitude and its base extending from longitude 100° (east of Hartney) to 114° along the 49th parallel. Palliser (1968a:3,18) did not expect that the arid plains would ever be occupied by settlers because the area was devoid of timber and lacked pasture of good quality:

> Even on alluvial points in the bottom of the valley trees and shrubs only occur in a few isolated patches...The sage and the cactus abound, and the whole scanty vegetation bespeaks an arid climate (Palliser 1968a:18).

Hind placed the border of the arid plains farther to the west, either at the Touchwood Hills (1971 II:234) or the Missouri Coteau (1971 I:350) because the "boundless, treeless" land extending from southeast Saskatchewan to the Red River Valley was "Prairie country, over the greater portion of which forests of aspen would grow if annual fires did not arrest their progress" (Hind 1971 I:245-246,350).

With the exception of his "treeless prairie" east of the Missouri Coteau, Hind (1971 I:349-350) reserved the term "prairie" for the land between the heavily wooded region of the north and the treeless plains, an area where trees were "not crowded together, but scattered over the surface at a considerable distance from one another, without any low shrubs or underbrush between them." Hind's term "prairie" corresponds to the "fertile belt" and to Palliser's term "fertile country", an area denuded of timber separating the arid region from the forest lands to the north (Palliser 1968a:9). Hind (1971 II:234) described the fertile belt as a "broad strip of fertile country, rich in water, woods, and pasturage" (Figure 1). The land adjacent to the North Saskatchewan River was most desirable for human settlement; fine grazing land, sometimes 50 km in width, flanked the river and "as it all lies within the limit of the partially wooded belt of country, there are 'bluffs' that will afford shelter to stock" (Palliser 1968a:16). Within the fertile belt, excellent hay for animals was available and settlers would not "encounter the formidable labour of clearing the land of timber" (Palliser 1968a:20-22).

The frequent fires which continually traverse the prairie have denuded the

> territory of large forest trees, indeed so much so as in some places to render their absence deplorable, and the result of these fires is that the agriculturist may at once commence with his plough without any more preliminary labour (Palliser 1968a:22).

Although the fertile belt is narrower and shifted north of the modern placement of the parkland, Spry (1968:cvii) considers this clearly defined belt of vegetation to be the "Park belt", i.e. the aspen parkland. Descriptions of the fertile belt are consistent with Bird's (1961:2-3) definition of the aspen parkland, "forest and grassland, which are intermingled in a mosaic of irregular patches and more or less solid stands" which represent a recent invasion of aspen upon an area that had been in grass for a considerable period. Any suggestion that the fertile belt is comprised of only the most heavily wooded, northern portion of the parklands is not supportable. Palliser (1968a:9, 20-22) considered the task of clearing land to be the most arduous labour of the colonist; the suitability of the country for settlement had gradually improved because Indians were in the habit of burning the vegetation so that the fertile belt was denuded of timber. The burning of the grasslands promoted new growth to attract grazing animals and reduce the invasion of brush and trees (Lewis 1982).

In summary, descriptions of vegetation made by European travellers to Western Canada in the 1700s and early 1800s are confirmed by Palliser and Hind. For this reason, Hind's map is particularly appropriate for discussing seasonal movements of bison and human hunter-gatherers with respect to the limits of the plains, parkland and southern boreal forest during the early historic period. Since this record was made at the end of the Little Ice Age, an extended period of below average temperatures, the southern boundary

of the parkland may have been at or near a post-glacial (Holocene) maximum (Dyck 1983:65-68). The map was made when the impact of prairie fires, of both natural and cultural origin, and grazing by large herds of bison were still reflected in the vegetation patterns. It is quite possible that the limits of the parkland and forest portrayed on Hind's map actually existed for much of the Middle and Late Precontact Periods.

While the limits and character of the parkland are of interest, the location of the southern boundary of the parkland / northern boundary of the grassland is also important. As discussed by Meyer and Epp (1990), the parkland is not homogeneous; there is a north-south gradation in vegetation. While the vegetation on the northern edge of the parkland is quite dense, the southern edge is characterized by wide expanses of open grasslands with the number and size of aspen copses gradually reducing until they disappear altogether. The actual placement of the southern parkland/northern grassland edge may have varied considerably because the sparse vegetation was vulnerable to the effects of prairie fires and drought. For this reason, the southern edge of the parkland/northern edge of the grassland is considered to be a transition zone.

Chapter 3. The Seasonal Movements of Bison and People

While bison moved onto the northern parts of the plains during the fall and winter, historic records indicate the majority of bison did not winter in the sheltered parkland. Contrary to expectations, vast herds of bison were observed on the grassland in December, January and February, even at the end of the Little Ice Age. While herds approached sheltered areas if there was a severe storm or extended periods of cold weather, there are no reports of similar concentrations of bison in the parkland. Even in a normal winter, bison frequently did not reach many of the fur trading posts situated in the parkland. Just as historic accounts show that bison spent the winter on the plains, there is a substantial body of historical and archaeological evidence of winter camps in this region. The historic accounts of this pattern include some of the earliest reports from the interior of Western Canada. Evidence in the archaeological record extends this practice back 3000 years into the Precontact Period.

3.1 Reports from Alberta

Entries in the journals of traders wintering along the North Saskatchewan River show that bison herds did not enter the hunting range of forts in central Alberta until late in the year, if at all. In 1795 and 1796, bison did not arrive in the vicinity of Edmonton House until late November (Tomison 1967:17; Sutherland 1967:74; Figure 2). The following two winters, 1797-1798 and 1798-1799, the animals did not approach Edmonton House until the beginning of January (Tomison 1967:106; 1967:151). The winter of 1799-1800 was so mild that bison were scarce throughout the entire season (Bird 1967:241). On 9 January 1858, Hector (1968:201), the botanist in Palliser's

expedition, noted that it was difficult to supply the 150 inhabitants of the nearby Fort Edmonton with bison meat:

> the loss of horses from dragging the meat during the severities of the winter, and the number of men employed for this purpose, alone renders it a very expensive mode of feeding the establishment, although the first cost of the buffalo, when killed in the plain, is merely nominal. This year these animals are within a few days of the fort, and it is accordingly well off; but many years there is great scarcity, and even starvation here.

At the posts in east-central Alberta, bison moving from the east usually ventured close to the forts slightly earlier. On 30 October 1794 at Fort George, M'Gillivray (1929:38) noted that "vast herds of Buffalo are at the Paint [Vermilion] River" (Figure 1). In 1809, Henry tracked the movement of large herds from Saskatchewan into Alberta. On 18 October 1809, there were no bison on the west side of the Battle River (Henry 1992:407); by the end of November, they were abundant about one-half days journey from the fort (Henry 1992:418). Bison finally arrived in the vicinity of Fort Vermilion in mid-December (Henry 1992:421). In January 1810, Henry (1992:425) was informed by one of his men that during the winter these bison always move against the wind.

While most historic accounts were provided by traders stationed in the parklands for the winter, a few observations were made by Europeans travelling and trading within the plains. According to Morton (1973:247), Anthony Henday's 1754-1755 trip inland took him through central Saskatchewan past Manito Lake near the Alberta-Saskatchewan border then across the Northern Plains close to the Battle River. The bison were so numerous on the level treeless plains around Manito Lake on 15 September his party was "obliged to make them sheer out of our way" (Henday 1973:27). Henday twice

commented on the vast numbers of bison out on the plains while the group travelled along the Battle River in early October (Henday 1973:29). Henday's party of Cree broke up into small parties to hunt beaver in the bush country to the west of modern Red Deer for two months "though often forced to move out into the open prairies to hunt buffalo for provisions" (Morton 1973:248). At the end of December the group began slowly travelling to "Archithinue Lake" where bison and moose were plentiful; Morton (1973:248) identified this lake as Saunders Lake, located about sixteen kilometres northeast of modern Wetaskiwin. In April, as they travelled in the parkland towards modern Edmonton, his party hunted moose, elk and bison (Henday 1973:42-43).

Peter Fidler travelled south from the Hudson Bay Company's Buckingham House, neighbouring North West Company Fort George, in November 1792 to winter with a band of Peigans near the Rocky Mountains. His party left the fort on 8 November 1792 travelling overland in a southwest direction. MacGregor (1966:66) estimates the group was about 10 km east of Red Deer when Fidler wrote that they had been living off bull bison meat because the cows were to the south. At the beginning of December, the group was probably 22 km east of Carstairs when they first established a bison pound (MacGregor 1966:68). In December and January, Fidler noted the operation of many pounds and jumps in the vicinity of modern Calgary, including Old Women's Buffalo Jump (MacGregor 1966:70-73).

Fidler's party began the return trip to Buckingham House in early February. On 12 February 1793 the party was near the modern town of Carbon when Fidler remarked:

The Buffalo are very numerous on the NE side of the Red Deers River &

> near it...from the N to S the ground is entirely covered by them & appears quite black. I never saw such amazing numbers together before. I am sure there was some millions in sight as no ground could be seen for them in that compleet semicircle & extending at least 10 miles (MacGregor 1966:82).

Ten days later they were still in the midst of vast herds (MacGregor 1966:83). On 1 March near modern Stettler, Fidler noted the Blood Indians had been operating a pound in the area for a long period of time (MacGregor 1966:85). The party then continued travelling northeast for several days. West of modern Mannville (MacGregor 1966:86), they passed a former winter camp of Canadian Free men. Fidler reported that the Canadian Free men who had been wintering there had recently abandoned their camp and moved west because bison were no longer in the area (MacGregor 1966:86).

3.2 Reports from Saskatchewan

There are numerous accounts regarding the presence or absence of bison in central Saskatchewan. In his narrative, David Thompson (1962:51) reported for "The Saskatchewan":

> Our subsistence was on the flesh of the Bison, hunted and killed on horseback to the middle of January, when the herds were driven into Pounds to the middle of March. During this time the women are busily employed in splitting the flesh into thin pieces and hanging it over the smoke to dry, and when dried it is a favourite food of all people.

Eleanor Verbicky-Todd (1984) compiled an exhaustive list of pounds described in historic and ethnographic accounts, including several which operated in Saskatchewan. The highest numbers of wintering bison and pounding activities documented in the historic record are located in the northern grasslands, not the parkland.

Contrary to expectations, there are several journal entries indicating a scarcity of

wintering bison within the parkland, even during cold winters. When Henry the Elder travelled between Cumberland House and Fort aux Trembles in January his party nearly starved. Although it was severely cold when they left Cumberland House on 4 January 1776 there was no trace of life until they reached Finlay's house, near modern Nipawin, when moose and elk tracks were seen (Henry 1969:269-271). Faced with a shortage of food before arriving at Fort Aux Trembles on January 28, his party subsisted on soup made from the bones of an elk killed by wolves and the remains of a red-deer which had broken through the ice earlier in that winter (Henry 1969:273-274). Game animals were also scarce on their return trip to Cumberland House between 22 March and 5 April. Henry the Elder (1969:322) reported "On our way, we saw nothing living, except wolves, who followed us in great numbers..." Information from the Hudson Houses, situated 22 kilometres apart along the North Saskatchewan River (Tomison 1952:69), shows that bison were equally scarce west of the confluence. There is no record of bison wintering around Upper Hudson House, even though the winter of 1778-1779 was severe (Longmoor 1951:323). In January 1780, bison were plentiful on the barren ground four days journey to the south of the Lower Hudson House (Tomison 1952:84), which made the 1779-1780 winter very prosperous for the trading house. When they returned to the post in the fall of 1780 and again in 1781, the traders reported that the plains in the vicinity of the trading house had been burned. The 1780 fire forced bison out of the entire region, causing every one to face starvation that winter. The following winter bison were scarce until the end of December 1781, but by mid-January thirteen of his men were camping on the barren plains (Walker 1952:273-276). On 27 March, the men returned to

Hudson House healthy and well to be refitted and were sent out for another month to "the Barren ground to be maintained or to maintain themselves where Buffalo is" (Walker 1952:284). The location of their camp(s) is not provided, only that the men were sent "far away in the Barren Ground" (Walker 1952:288).

Harmon's journals from Bird Mountain and Fort Alexander show that bison did not venture into the parklands of east-central Saskatchewan. Bison were never reported at Bird Mountain and the inhabitants usually relied on meat from Fort Alexandria (Harmon 1957:53-54). The only instance of bison approaching Fort Alexandria itself was recorded on 17 February 1800 when Harmon (1957:44) noted: "This morning one of our People killed a Buffaloe in the Plain opposite the Fort & another came within ten Rods of the Fort Gate..."

The numbers of bison increased closer to the northern grasslands but the populations were not necessarily stable or reliable. Records indicate that there usually were great numbers of bison in parts of the northern grasslands of west-central Saskatchewan in the late summer and early fall. There were vast numbers of bison near Manito Lake in mid-September 1754 (Henday 1973:27). When west of Manchester House on 26 September 1794 M'Gillivray (1929:28) reported, "Buffalos are exceedingly numerous,-from the summit of a hill which afforded an extensive prospect, we observe the face of the country entirely covered by them, in short they are numerous as the locusts of Egypt..."

In the early fall, huge herds of bison were regularly found along the North Saskatchewan River south of the forks of the North and South branches to the Eagle Hills.

William Pink travelling overland from a fort at the forks in August 1769 encountered bison in the large plains of the Minichinas Hills, between modern Batoche and Humboldt (Russell 1991:102-103). Their numbers increased as Pink travelled south and west in mid-September; however, there were few bison west of the Eagle Hills at this time. On 6 September, 1808, while travelling south along the North Saskatchewan River northwest of modern Saskatoon, Henry (1992:355) "observed the plains covered with numerous herds of Buffalo as far as the eye could reach on both sides of the River....The Red Berry Hills appear entirely covered with Buffalo feeding." The following day, the number of bison he saw on the "Plains" around the elbow of the river was "astonishing" (Henry 1992:358). Huge herds of bison were found along the North Saskatchewan River from the forks of the North and South Branches to the Eagle Hills. In 1795 and 1796, when travelling to their post in September the Edmonton House traders encountered large herds above the forks of the North and South Saskatchewan Rivers (Tomison 1967:17; Sutherland 1967:74). In September 1808, Alexander Henry the Younger travelled through central Saskatchewan en route to Fort Vermilion and noted that the numbers of bison diminished as his party journeyed west (Henry 1992:361-365).

An abundance of bison in west-central Saskatchewan was not guaranteed for the duration of the fall and winter. Near the modern town of Biggar (Russell 1991:106), Matthew Cocking (1908:108) reported bison were very scarce on 7 October 1772 and his Cree travelling companions were unable to pound those which were there. In early December 1772, Atsina Fall Indians told Cocking's Cree companions that "the season is past"; there were too few animals in the Bear Hills of west-central Saskatchewan to

successfully operate a pound (Cocking 1908:111; Russell 1991:107). Cocking's companions had intended to spend the entire winter in the area but due to a shortage of bison they were forced to move to land between the branches of the Saskatchewan River. The absence of bison at the end of February 1793 caused a group of Assiniboin to travel several days from west-central Saskatchewan to near modern Stettler (MacGregor 1966:85).

Reports from central Saskatchewan indicate the wintering herds were often, but not always found in the region. After departing Fort á la Corne in the fall of 1772, Cocking remarked "...Indians tell me that in Winter buffalo are plenty here, which is confirmed by the quantity of Dung on the ground" (Cocking 1908:102). On 15 March 1806 at South Branch House, Harmon (1957:99) reported that bison "have been found in plenty, with in a few miles of the fort, during the whole winter." Yet in mid-February, 1773, a few kilometres west of the future location of South Branch House, bison were still very scarce and Cocking's party of travellers were starving (Cocking 1908:112-113). The group moved northeast where only a small number of bison were driven into pounds (Cocking 1908:116). When Alexander Henry the Elder travelled south from Fort aux Trembles to an Assiniboin camp in early February 1776 he observed elk tracks but no bison during the first part of the journey (Henry 1969:281).

Numerous accounts suggest that herds of bison were first encountered on the northern edge of the grasslands and the number of animals increased as one proceeded farther into the plains. When the Assiniboin group which Henry the Elder accompanied was within one day's journey from the camp, situated near modern Humboldt (Bain

1969:285), they encountered "a herd of oxen, extending a mile and half in length, and too numerous to be counted" (Henry 1969:283). Several herds were observed in the vicinity of the Assiniboin camp and on 13 February, 72 bison were successfully pounded (Henry 1969:300-301).

> The women brought the meat to the village, on sledges drawn by dogs. The lumps on the shoulders, and the hearts, as well as the tongues, were set apart for feasts; while the rest was consumed as ordinary food, or dried, for sale at the fort.

While bison rarely reached Fort Alexandria, bison moved into the grasslands south of the fort in the fall or early winter (Harmon 1957). A hunter camped out on the plains could supply the fort with meat throughout the winter, although sometimes the bison remained far out on the plains until January (Harmon 1957:39-40, 85). On 2 December 1800, Harmon (1957:39-40) returned to Fort Alexandria from the hunter's camp and wrote:

> The Country we past through in going there is a large Plain with here and there a Grove to be seen, and this evening we returned to the Fort, the Peoples Horses loaded with the Flesh of Moose & Deer. The Buffaloe are still a considerable distance farther out into the spacious Plains and nothing but severe cold weather, will drive them into the more woody part of the country.

Although it had been severely cold for some time, one month later bison still had not arrived within range of the hunter's camp (Harmon 1957:40). As a result, he sent men, women and children out to winter on the plains two days journey from the fort "where they will live upon the flesh of Buffaloe which they will kill themselves" (Harmon 1957:41). Later that January, Harmon (1957:42) travelled to the hunter's camp and "remained there to go farther into the Plains along with the Hunter, and where I am sure I

saw in different herds at least a thousand Buffaloe grazing..." That February, he made a three-day journey across the plains to trade at a Cree and Assiniboin camp (Harmon 1957:42). Harmon (1957:44) reported

> In our excursion we saw Buffalo in abundance, and when on a small rise of ground I may in truth say that we could see grazing in the Plains below at least five thousand of which Animals we killed what we wanted for ourselves & Dogs.

The numbers of bison in parts of the northern grasslands were considered a hazard to travellers in the open plains. In the beginning of March 1804 when Harmon and a companion were walking towards Good Spirit Lake (Lamb 1957:73 n.36) at night, they were worried the large herds of buffalo could trample them in the dark (Harmon 1957:73-74).

From Harmon's observations it is clear that the distribution of bison was not even across the Northern Plains of southeast Saskatchewan during the winter. While at Lac la Pêche or the Fishing Lakes in January and February 1804, Harmon (1957:72) noted, "For some time after our arrival we subsisted on Rose-buds! which gathered in the field..., for the Buffalo at that time were a great distance out into the Plains & my Hunters could not kill, either Moose or Deer...." After travelling "several days march farther into the Plains" they came to a Cree and Assiniboin camp, situated at the summit of a hill "from whence we had an extensive view of the surrounding Country, which lay low & level and not a Tree to be seen, but thousands of Buffaloe were grazing in the different parts of the Plain" (Harmon 1957:72).

Bison were found in abundance in the vicinity of Fort Espérance in the fall and

winter. John Macdonell (1984:87, 96) reported bison pounds operating in the area between November and February in the winter of 1793-1794. In October 1794, there were great herds of bison a short distance from the fort and pounding began at this time (Macdonell 1984:111). Bison populations appear to have been stable in the vicinity of the fort throughout the winter. Macdonell (1984:125) indicates that by mid-February 1795, a total of 89 animals had been killed by the two hunters employed by the fort.

At the turn of the nineteenth century, bison were abundant and available throughout the fall and winter in the vicinity of Chesterfield House, located far out on the plains (Fidler 1967:268). Bison were so plentiful in the fall of 1800 that Fidler ran out of trade goods on 1 December, having already accumulated 2000 lbs of bladder fat and 2000 lbs of back fat and dried bison meat (Fidler 1967:277-278). The following year, bison were abundant by 15 November (Fidler 1967:300). On 11 January 1802, Fidler (1967:306) wrote, "Millions of buffalo all round the house not 1/4 mile off..."

3.3 Reports from Manitoba

On the basis of fur trade accounts, bison were readily available on the northern edge of the grasslands of Manitoba in the winter. When Harmon visited Montagne á la Bosse in 1804, he (1957:84) noted, "we can from the Fort Gate (as I am informed) at almost all seasons of the year see Buffalo Grazing or Deer & Cabri [antelope] bounding across the Plains." Bison were found in the grasslands of southwest Manitoba in winter. In early December 1797, David Thompson travelled to the Missouri River villages along the Souris River through southwest Manitoba. While Thompson's party was able to feed themselves and their dogs, only small bison herds, composed of less than twenty animals,

were seen (Thompson 1962:167). Large numbers of bison were not encountered until the party reached "the Elbow of the Missesourie or its Northern Extremity", near the Missouri River villages (Thompson 1985:111).

Bison appear to have entered southeast Manitoba in late August and may have remained in the vicinity for several months, however, neither bison nor any other game animals were present in the latter stages of winter. Journal entries from 1801 show that bear, moose, elk, raccoon and birds were hunted in the fall and early winter (Henry 1988:56-99), but by late winter Henry's people were subsisting on boiled tree bark (Henry 1988:111). John Tanner (1956:58) and David Thompson (1962) also report there was very little else in the region to eat in late winter.

3.4 Summary of Bison Movement

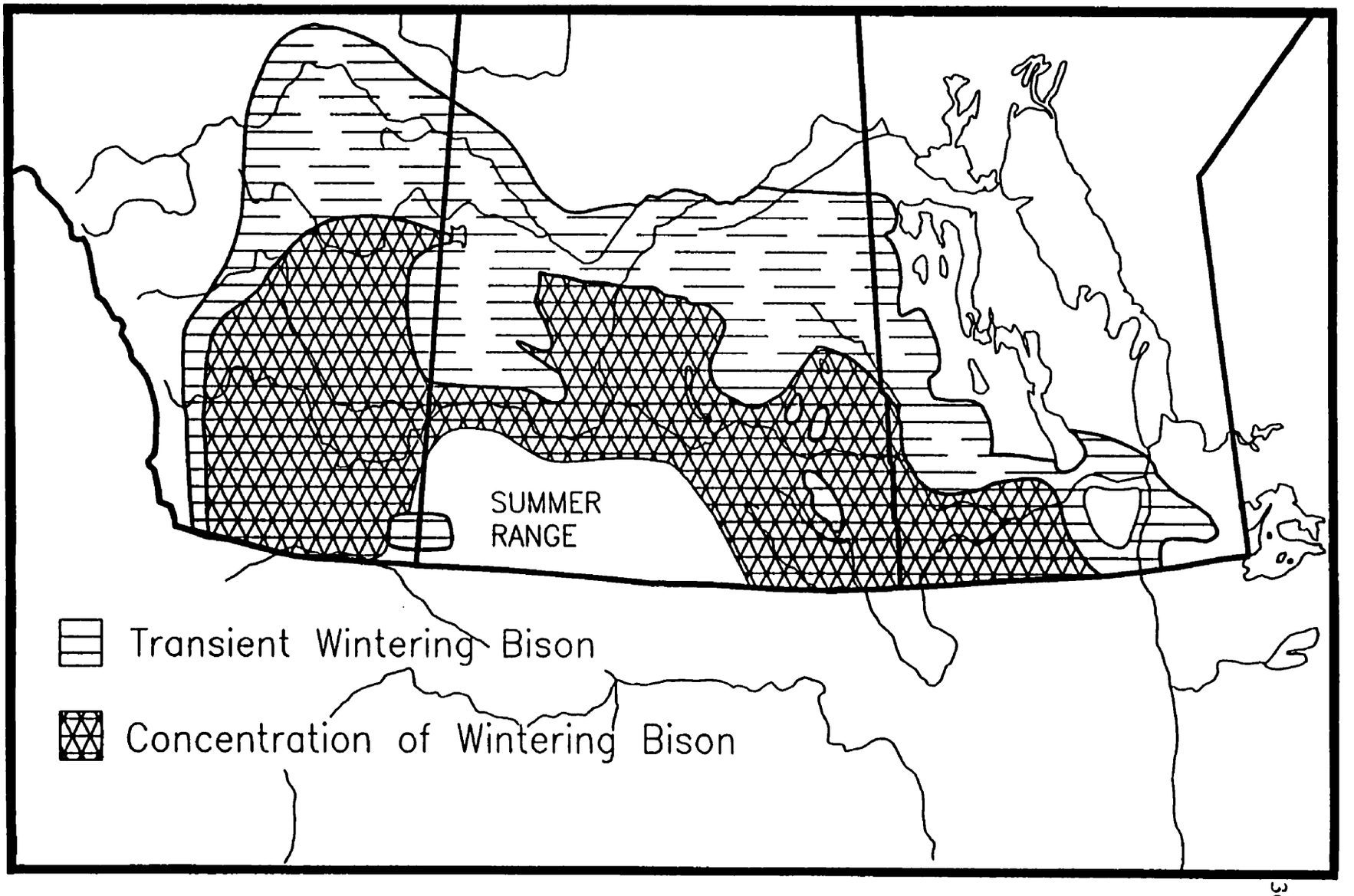
The highest and most stable concentrations of bison in winter were found in the northern grasslands; transient populations of bison wintered in the parkland. Vast numbers were found on the plains of Alberta and Saskatchewan and along the Missouri River in North Dakota throughout the winter. Some of the largest masses of bison observed were located on the plains, far from the parklands, in February (Harmon 1957; MacGregor 1966; Fidler 1967). Some herds gradually moved to the northern parts of the grasslands and southern parkland over a normal winter, but virtually all remained on the open grasslands if the weather was mild. Some bison usually approached or entered the parkland over the course of the winter but these herds were transient. The distribution of these animals was not uniform across the Northern Plains. Records from Fort Alexandria show that bison did not regularly enter the parkland in eastern Saskatchewan. They

wintered in the vicinity of Good Spirit Lake and Fort Espérance but they were not always found near the Fishing Lakes of the Qu'Appelle Valley. Bison were abundant in central Saskatchewan in September but numbers sometimes dwindled over the course of the winter. It appears that significant numbers of bison regularly moved west into east-central Alberta as winter progressed. Large numbers of bison could often be found in the plains south of Fort Vermilion until March. During a normal winter, bison were within hunting distance of central Alberta forts by the beginning of January.

Contrary to expectations, the records of trading posts do not indicate there were large aggregations of bison in the parkland over the winter. Instead, the various parkland trading posts were provisioned by bison hunters camped out on the plains; the meat was dragged back to the forts by horses. As noted earlier, the situation at Fort Edmonton in 1858 was manageable because the bison wintered only a few days away. Other years the bison were much farther away and the inhabitants of the fort faced starvation. During the winter, large herds of bison were only observed by the travellers and traders who ventured out onto the plains; large herds were not found in the sheltered parkland.

The probable distribution of bison in winter, based on historic accounts and geographical considerations, is presented in Figure 3. The southern limit of wintering bison for southwest Saskatchewan is based on Morgan's (1980:155-56) delineation and includes the Mesic Mixed Prairie, the Fescue Prairie of the Aspen Grove Parkland, the transitional grasslands of the Aspen Grove Region and the Qu'Appelle-South Saskatchewan River Valley complexes. On the basis of historic accounts, it appears that the barren uplands of the Eagle and Bear Hills of west-central Saskatchewan and the

Figure 3. Distribution of wintering bison populations on the Canadian Northern Plains.



Neutral Hills of east-central Alberta had lower concentrations of wintering bison than the surrounding lowland plains. These areas may have been more suitable for supporting large numbers of bison in either the fall or spring. With the acceptance of Hind's (1971) vegetation boundaries, which differ from those employed by Morgan (1980), it is necessary to extrapolate the southern range of wintering bison eastward. The treed uplands of Moose Mountain and the Thickwood Hills were probably areas of transient populations of bison seeking shelter under severe weather conditions. Following Epp (1988), it is possible that sedentary bison herds remained in anomalous treed areas, such the Souris River Valley, throughout the winter.

The distribution of wintering bison in Manitoba is more difficult to estimate because modern vegetation zones are very different than those recorded in the Early Postcontact Period. On the basis of modern vegetation patterns which show the area to be aspen parkland, Morgan (1980:157) identifies most of southern Manitoba and adjacent southeast Saskatchewan as winter range. According to Hind's (1971) map and first hand observations, however, this area was grassland in the early historic period. The winters are more severe in southeast Saskatchewan and Manitoba because the area is out of the range of chinooks. As a result, the highest concentrations of bison were probably most stable in the grassland closest to the parkland, the Souris Valley/Pembina Trench. Populations of wintering bison were probably stable in the Missouri River Valley to the south, as well. Based on the behaviour of bison in the Eagle and Bear Hills of west-central Saskatchewan, it seems likely that the upland areas of the Manitoba Escarpment would be avoided by wintering bison populations if the area lacked trees, as Hind (1971)

suggests.

3.5 Historical Evidence of Winter Camping and Hunting

Historical observations, made over a long period of time, indicate that large Native encampments were located in the grassland over the winter. The camps of plains-dwelling groups were located far out on the grasslands where the largest and most stable populations of wintering bison were found. Early historic records indicate parkland and forest-adapted Natives, canoe men not required for the daily operation of the fur trade houses, and the hunters hired by fur traders to supply them with meat formed winter camps on the northern edge of the grasslands. From this location, these people usually had access to wintering bison while maintaining their distance from plains groups.

Evidence of this pattern dates to the earliest accounts of Europeans wintering inland. As shown below, forest- and parkland-dwelling groups are frequently recorded wintering along the northern edge of the grassland and in the Eagle and Bear Hills of west central Saskatchewan, in the vicinity of Ruthilda (Figure 1). Joseph Smith spent the winter of 1763-1764 with a group of Cree in west-central Saskatchewan. They skirted the northern edge of the grassland, moving to the plains east or south of the Eagle Hills at the end of November when they learned no Archithinue (Plains Indians) were nearby (Russell 1991:97-98). In mid-January the group journeyed east to South Saskatchewan River where the Cree pounded bison. They continued up the river until reaching their canoe building grounds in the Birch Hills on 21 March.

> Despite the difficulties in Smith's journal of 1763, the first account of wintering in Saskatchewan, it is clear that his Cree companions were wintering, as long as possible, on the grasslands and only entering the edge

> of the forest, while remaining within the wintering range of bison, to prepare for the trip to the Bay (Russell 1991:98).

William Pink travelled in the area from 1766-1770 (Russell 1991:98-105). Pink covered a large territory during his four trips inland, "Yet he seemed to always winter in the same general area: the open country either west or south of the Eagle Hills" (Russell 1991:105). In 1772-1773, Matthew Cocking journeyed inland with a Cree group which planned to spend the winter in the Bear Hills (Russell 1991:107).

There are also records of canoe men establishing winter camps on the northern edge of the plains. After the canoe trip to the trading house was complete, most of these men were not required for the normal operation of the establishment. Known as Canadian Free men, they were permitted to leave the fort and winter out on the plains where they could hunt and trap for themselves (M'Gillivray 1929:32). Fidler encountered the remains of a Canadian Free men camp west of modern Mannville in March 1793 (MacGregor 1966:86). The Free men had recently abandoned the camp and moved west to find bison. When food was short at Fort Alexandria, Harmon sent men, women and children out to winter in the plains two days journey from the fort (Figure 2).

Hunters employed at Fort Vermilion were sent to the plains in late November to hunt bison (Henry 1992:417). Harmon's hunter for Fort Alexandria had a camp out on the plains; when hunting he ventured farther out on the plains.

There are numerous accounts of Native winter camps and pounds on the Northern Plains. M'Gillivray (1929:38) reported that the "strong woods Assiniboine" intended to establish a pound on Vermilion River in 1794. In December 1809, Henry the Younger

(1992:421-422) visited a pound near the Blackfoot camp situated nearby at the elbow of the Vermilion River. Starting at the end of January, Cree trappers travelled down from the forest with their furs to join the Cree camping and hunting bison farther south:

> Missistecione, a Cree, arrived with his family from the Strong Wood on his way to the Cree camps below. This is the first of my Crees that have come out of the Woods this Season, and once they take the route for the [buffalo] pounds below we expect no more Fur from them for this season, as they idle, playing and eating buffalo (Henry 1992:426).

One such Cree pound was located in the Horse Hills to the south (Henry 1992:428). On 8 February 1802, Harmon (1957:54) noted that the Fort Alexandria Indians "are gone to pass a couple of Months on their beloved food Buffaloe Meat"; most of these Indians returned from the plains by 20 March (Harmon 1957:55).

There is also evidence of groups wintering in the grasslands and southern edge of the parkland in central Saskatchewan. The large Assiniboin winter camp which Henry the Elder visited in 1776 was about eight days travel on foot from Fort aux Trembles, probably just south of modern Humboldt, Saskatchewan (Bain 1969:285). On the return trip, they went past another large camp of Assiniboin (Henry 1969). Farther south, Harmon met an Indian camp at Last Mountain Lake on 1 March 1801, but he did not identify them ethnically (1957:73). Cocking, who spent the winter of 1774-1775 at Good Spirit Lake, noted there were Assiniboin and Cree camps to the west hunting and pounding bison (Morton 1973:304; Russell 1991:116). Large Cree and Assiniboin camps were also located around Good Spirit Lake in 1804; French-Canadians established winter camps in the vicinity that winter, as well (Harmon 1957:73-75).

In spite of the harsh winter weather, numerous groups were found wintering far

out on the open grasslands. The Blood Indians wintered on the plains of south-central Alberta. In February, Fidler observed a Blood Indian camp and pound near modern Stettler and he noted the Indians had been camped there an extended period of time (MacGregor 1966:85). Fidler spent the winter of 1792-1793 with the Peigans in southern Alberta. He noted several camps in the vicinity of Calgary including one of 700 Peigans in December (MacGregor 1966:70) and another consisting of 190 Peigan tents, 13 Blackfoot tents, 12 Sarcee tents and 5 Plains Cree tents, who had come together to pound bison in early January (MacGregor 1966:80). Arthur (1978:241) estimates that 1760 people were in the latter camp. The number and size of these winter camps is noteworthy since the lack of firewood and shelter in the Calgary area should have made the area unsuitable for winter occupation (Vickers 1991:62).

The presence of large winter camps of plains-adapted Indians in the Saskatchewan grasslands is documented by Fidler during his sojourn at Chesterfield House. The entire nation of Fall Indians, including more than 600 warriors, had three pounds in operation in the area in January (Fidler 1967:307, 313).

The records of Harmon's trading expeditions show winter encampments were located on the plains and that proximity to trees, for shelter and fire, was not necessarily a priority. On 1 February 1801, Harmon went out to "trade with about fifty Families of Crees & Assiniboine and in going to their Camp or Village we were three Days always in Plain Country" (Harmon 1957:42). In February 1804, Harmon (1957:72) visited a winter camp consisting of thirty lodges of Cree and Assiniboin located "several Days march farther into the Plains" from the Fishing Lakes. Their camp was situated on the summit of

a hill, "from whence we had an extensive view of the surrounding Country, which lay low & level and not a Tree to be seen, but thousands of Buffaloe were grazing in the different parts of the Plain..." (Harmon 1957:72).

Groups worried about an encounter with their adversaries also camped in the open. In October 1754 Anthony Henday encountered a large camp of Blood Indians (Morton 1973:247) near modern Red Deer, Alberta. Henday (1973:33) noted, "They follow the Buffalo from place to place: & that they should not be surprised by the Enemy, encamp in open plains. Their fuel is turf, & Horse-dung dryed." It is not known whether this practice continued into the winter.

While en route to the Missouri River Villages, David Thompson met an Assiniboin camp consisting of eight tents in the Lauder sandhills, southwest of Hartney in early December (Thompson 1985:101). In early February on his return trip, Thompson (1985:126) noted "Co N6E 3M to the Sand Knowls where we again found the Same Indians in the same Place." The party met two other Assiniboin camps before reaching the forts at the mouth of the Souris River. The path the men travelled north along the Souris River, "the great Road of the Stone Indians", was so well packed down that no snowshoes were required to walk on it (Thompson 1985:127). Alexander Henry the Younger (1988:209) indicated that Assiniboin and Cree frequently hunted along the borders of the Missouri plains in the winter.

3.6 Archaeological Evidence of Winter Camping and Hunting

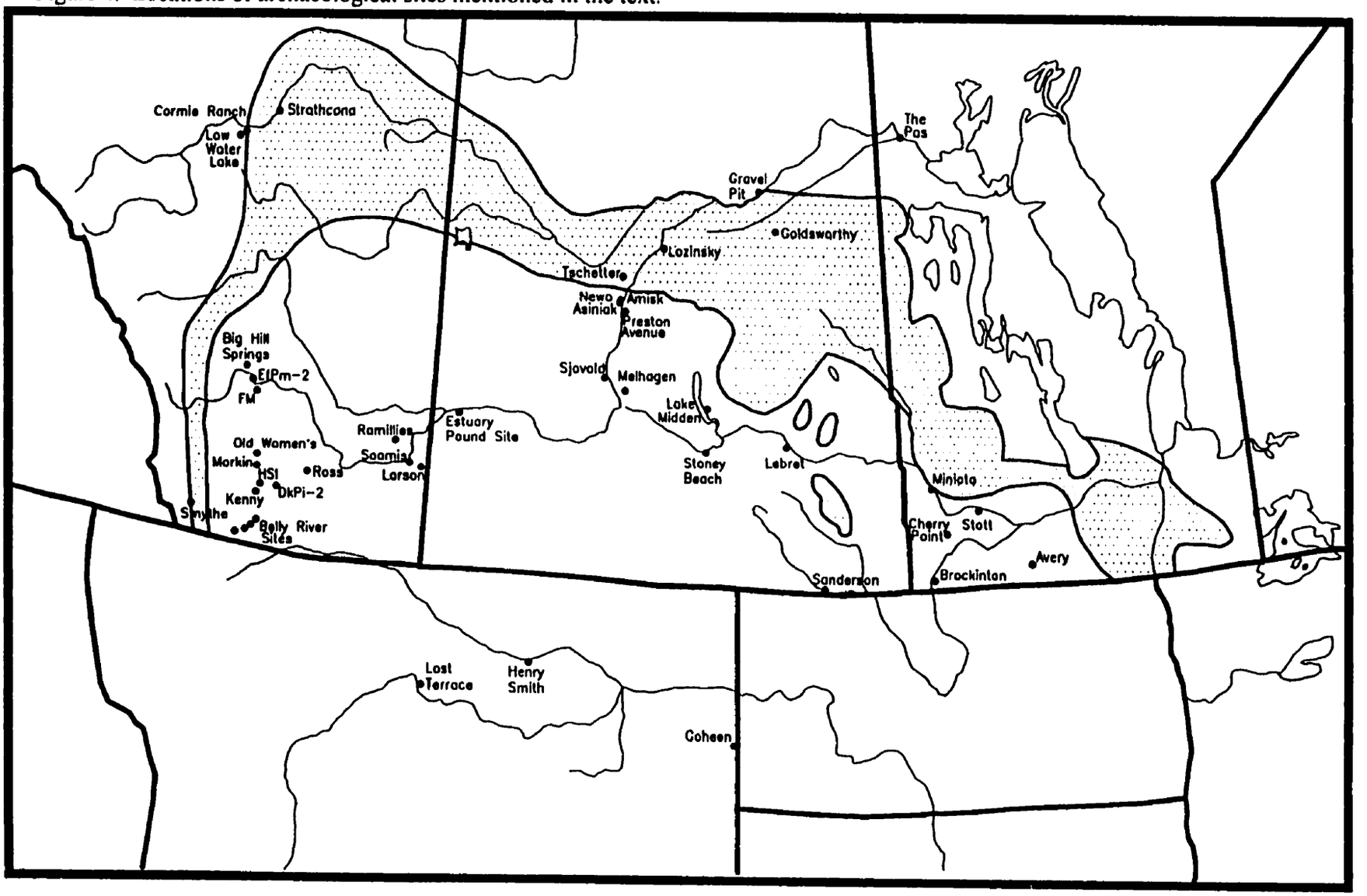
Early historic accounts show large populations of wintering bison were located on the northern grasslands and provide several examples of Native winter camps in the area.

There is also considerable archaeological evidence of Native winter and spring camps and kill sites on the plains. Seasonality indicators which are generally used to establish time of death of bison are tooth eruption patterns and the presence of foetal bone. The tooth eruption patterns for immature bison are known; by examining several specimens the age profile of the death assemblage can be determined (Fuller 1959; Reher and Frison 1980; Wilson 1988). The presence of foetal/newborn bison bone and the stage of development of that bone are also important indicators of seasonality (Quigg 1978). The calving season for bison runs between mid-March and May with peaks in April (Arthur 1975:52).

Research indicates there are a substantial number of Precontact and Early Postcontact winter camps on the northern grasslands both in the Prairie Provinces and the Northern Plains States (Figure 4). Some of the best examples of these sites are from Alberta where seasonality studies are routinely undertaken as part of the site analysis. Many of these winter camps are located along rivers, where vegetation similar to that of the parkland was supported. Owing to the presence of trees for fuel and bison for food, it was simply not necessary for hunter-gatherers to abandon the plains in winter. The highest number of known sites in the region were occupied during winter; these winter encampments also represent the largest documented sites.

Foetal bison bone has been identified at large campsites, small campsites and kill sites dating to the Late Precontact and Early Precontact Periods in Alberta (Quigg 1978; Vickers 1991). Both the Saamis site, EaOp-6, (Milne-Brumley 1978) and the Larson site, DlOn-3, (Milne 1988), in southeast Alberta are considered winter camps based on the presence of foetal bison bone and the high concentration of artifacts around hearths

Figure 4. Locations of archaeological sites mentioned in the text.



(Figure 4). The Ramillies site, EcOr-35, a bison kill and campsite located north of Medicine Hat, was repeatedly used in the Late Precontact Period (Brumley 1976). Several post-cranial elements from an unknown number of foetal or newborn bison calves were recovered, although dental eruptions and wear patterns also indicate spring, summer and fall use of the pound.

The major occupation at the Ross site, DlPd-30, on the Oldman River was during winter (Vickers 1991). The artifact densities of the main winter occupation, 375 items/m^2 including bone, were almost four times higher than that of the spring occupation (Vickers 1991:61, 65). Another winter camp/kill site is the FM Ranch site on the Bow River (Vickers 1991; Quigg 1978:55). Quigg's (1978) discussion of winter camping in southwest Alberta also included Kenny, Morkin and several small sites along the Belly River Valley, all of which are situated on river valleys on the western margin of the plains. Little Bow site, situated on a high terrace above the Little Bow River, also contains foetal bison bone. Based on artifact densities and site size, Little Bow was probably occupied for several weeks by a band sized group engaged in intensive bison exploitation (Vickers 1991:61). Vickers (1991:61) also identified the Hartell Creek site, just east of Calgary, and the Balzac site, just north of Calgary, as spring bison procurement camps with high densities of faunal material. These sites are all multicomponent Late Middle and Late Prehistoric encampments, suggesting that the settlement-subsistence pattern was well-established (Vickers 1991:62).

Several winter and early spring events have been identified at Alberta kill sites.

Winter kill episodes have been recorded at Head-Smashed-In (HSI), Big Hills Springs and Old Women's bison jumps (Reeves 1978:161; Quigg 1978:55; Arthur 1978). The recently discovered site DkPi-2, near Fort MacLeod, reportedly represents a winter kill site (Unfreed 1994). Vickers (1991:62) also identifies the Fort MacLeod kill/camp and Gleichen Jump as spring kill sites. Fall kill sites are rare in Alberta. Vickers (1991:64) mentions only EfPm-2, a small pound on Fish Creek in Calgary, and fall components at the Smythe site, a large kill site on the Oldman River.

High frequencies of winter kill episodes also occur in northern Montana. The Henry Smith site is a multicomponent Avonlea bison kill located on the Milk River (Ruebelmann 1988:191). The lower dentitions from at least 120 individual animals were examined in order to assess kill seasonality (Wilson 1988). While animals were killed throughout the year in small-scale drives, Wilson (1988:222) reports the peak period was winter, especially late winter, and summer. Fall kills have the lowest frequency at the site.

A growing number of seasonality studies undertaken with materials from Saskatchewan sites indicate that winter kills are quite common throughout the Late Precontact Period. The Melhagen site is a Besant site with foetal bison remains as evidence of a winter kill (Ramsay 1994). The Estuary Pound Site, EfOk-16, located near the confluence of the Red Deer and South Saskatchewan Rivers, contains a mixed Old Women's and Avonlea component (Adams 1977). Formed foetal fragments were recovered from this occupation suggesting that the kill occurred sometime between early February and late April (Adams 1977:96).

The Old Women's Phase pound at the Tschetter site (FbNr-1), near Saskatoon,

was utilized from November to the end of January (Walker 1979; Linnamae 1988). The highly weathered state of the faunal materials make it impossible to firmly establish the season of occupation of the Losinsky site, a bison kill and camp site (Malainey 1995a). One possible foetal bison bone and the presence of bison this far into the parkland suggests a fall/winter occupation. Large winter camps are found on the northern border of the plains of Saskatchewan. Meyer and Epp (1990:333-334) designate the Newo Asiniak, Amisk and Preston Avenue sites located in Saskatoon as fall/winter sites. The major occupation of the Preston Avenue site is represented by cultural materials transitional between Avonlea and Old Women's Phase, concentrated in a willow copse and poplar bluff, and has been renamed the Hartley site, FaNp-19 (Meyer 1994). Foetal bison bones are regularly found during the on-going excavations of the major occupation.

There are terminal Precontact and very early Postcontact winter camps in south-central Saskatchewan. The wide range of foetal bison bone development observed in Lake Midden, EfNg-1, recoveries indicate that it was occupied during the fall, winter and spring (Walde 1994). Few faunal remains were collected from the Stoney Beach site, EdNh-1, but Walde (1994:334) suggested a late fall to early winter occupation on the basis of a single foetal bison humerus. An ice-glider, a device used in a winter sport, recovered from this site implies a winter occupation (Walde 1994:345). Winter sites are also known from the Souris River Valley, east of modern Estevan in southeast Saskatchewan. Foetal bison remains were recovered from the Sanderson site, DhMs-12, a large late Precontact-Early Postcontact camp, indicating that it was occupied during the winter (Magee 1997).

Syms (1977:141) noted "All habitation sites in Southwestern Manitoba have a dominance of bison...This subsistence emphasis is in marked contrast to sites in the Aspen Parkland, where bison were supplemented by a variety of game." This observation generally holds for sites in Alberta and Saskatchewan, as well. The faunal assemblage of winter sites on the plains is dominated by bison; it is therefore necessary to rely heavily on seasonal indicators from these remains. Typically winter and spring sites in the parkland of Western Canada contain a wider variety of faunal material and most tend to be fairly small. Large winter kill/camp complexes are not known from the parklands of central Alberta (Vickers 1991:65). Bison, elk and moose were recovered from the Cormie Ranch site, FiPp-300, and the Low Water Lake site, FiPp-302, located about 70 km southwest of Edmonton, although deer, waterfowl, beaver, muskrat and other small mammals were also found at the latter site (Losey 1978). Losey (1978:153) suggests the co-occurrence of bison, moose and elk in the sites indicates a fall occupation. Bison, elk, moose and waterfowl were also found at the Strathcona site, FjPi-29, in Edmonton (Prager 1985). Following Losey's (1978) argument, a late fall occupation is suggested. These conclusions are not supported by Henday (1973) who noted that both bison and moose were plentiful in the vicinity of modern Wetaskiwin (Morton 1973:248) at the end of December. In April, the Natives he travelled with hunted moose, elk and bison along the North Saskatchewan River, near modern Edmonton (Henday 1973:42-43).

Avonlea sites containing a variety of faunal remains, including fish, have been found in southeastern Saskatchewan and southwestern Manitoba. The Lebret site, EeMw-26, has been identified as a spring or fall Avonlea fishery located on the Fishing Lakes

(Smith and Walker 1988). The faunal assemblage at the site was varied, including bison, deer, small mammals, waterfowl and fish (Smith and Walker 1988:85-86). Landals' (1994) investigation of the Miniota site, EaMg-12, in the parkland of southwestern Manitoba, indicates it is very similar to the Lebret site in that it contains bison and fish. This Avonlea site has been designated as a late winter-early spring occupation.

The season of occupation at other Manitoba sites is less precisely known and the indicators used in the seasonal determination are not always reported. The Blackduck component (Occupation 2) of the Brockinton kill/camp site, south of Melita represents an autumn, winter or spring camp (Syms 1977:136). The Blackduck component at the Cherry Point bison kill located farther north on Oak Lake is reported to be either a spring or autumn occupation (Syms 1977:136). The Stott site, a bison kill near Brandon, has been identified as an autumn kill site (Syms 1977:136); however, Joyes (1988:231) considers the seasonality to be ambiguous, noting the presence of both foetal bison bone and fish remains. At least 15 species of mammals as well as a few bird remains have been recovered (Joyes 1988:231).

Syms (1977:134) suggested that the Avery site, an Avonlea site on the north shore of Rock Lake, may be a winter camp; however, Joyes (1988:230) favours a fall or early winter designation due to the near absence of foetal or newborn bison bone. While bison dominate the faunal assemblage, thirteen species of mammals, at least three species of birds and one amphibian were recovered from this site (Joyes 1988:230).

According to Hind's vegetation zones, sites such as Avery and Stott may not have been in the aspen parkland, at the time of occupation. Pettipas (1980) suggests that Stott

was in the grasslands during the period it was in use but as both of these sites are situated in large valleys, the vegetation may have supported parkland species.

3.7 Discussion

Historic accounts and archaeological evidence indicate that the majority of mobile hunter-gatherers from the plains, parkland and southern boreal forest formed winter camps on the grasslands of Western Canada where bison populations were large and stable. Plains-adapted peoples wintered far out on the open grasslands, where the high populations of bison easily facilitated the use of jumps or pounds in communal hunts. Parkland- and forest-adapted people wintered in the grassland-parkland transition zone, encompassing the southern edge of the parkland and the northern edge of the grassland. Modern perceptions of the plains as too hostile and dangerous an environment to be inhabited in winter are not supported. George Arthur (1975, 1978) argued strongly that communal bison hunting persisted throughout the winter and most of the observations he cites were made on the plains. Fidler observed several bison pounds in operation around Calgary in late December and January. The only recorded locations of early historic Peigan and Atsina Fall Indian winter camps are the grasslands of southern Alberta and southwest Saskatchewan. Examples of Blackfoot and Blood establishing winter camps on the plains are also known.

There is little evidence that vast numbers of bison converged on the parkland in search of winter shelter. Almost all eyewitness accounts of large herds of wintering bison were from people travelling and trading on the plains. The vast numbers of bison wintering in the grasslands enticed parkland- and forest-adapted peoples out of wooded

areas to establish their winter camps near lakes and in aspen bluffs along the northern edge of the plains. Although the populations of wintering bison were smaller and less reliable, there were sometimes sufficient numbers in the area to operate pounds. This occupation is reflected in the archaeological record by winter sites on the plains/parkland boundary, such as those in the vicinity of modern Saskatoon. In the 1700 and 1800s, both their Free men and hunters hired by forts established their winter camps on the Northern Plains. When provisions were low, most of the men, women and children associated with the forts were sent out to camp in the plains. Traders wanting to conduct business with the Cree and Assiniboin in Southern Saskatchewan invariably travelled several days out into the plains before reaching their winter camps, some of which were established on the summits of hills. They are also known to have wintered on the barren grounds of the Eagle and Bear Hills. Winter camps of plains-dwelling peoples were situated far out on the grassland. Often these camps were formed along river valleys, but campsites were also located on the summits of hills and in areas lacking vegetation.

As the winter camps of plains-dwelling people were situated out on the plains where concentrations of bison were highest, Natives from wooded areas were able to exploit bison wintering on the northern edge of the grasslands with little conflict. The pattern of parkland- and forest-dwelling peoples venturing on to the Northern Plains during the winter is long established. As shown by Russell (1991:117), the earliest historic accounts have forest- and parkland-adapted groups wintering on the plains: "The Cree were clearly spending the winter as far out on the prairies as was necessary to go to find bison. The latter moved into the parkland only when conditions were severe out in

the open grasslands." Russell (1991:108) further argues that the information in the journals of Henday, Smith, Pink and Cocking all contradict Ray's (1974) suggestion that Indians who participated in the fur trade spent the harshest part of the winter in the parkland but remained in the forest in the milder early and late parts of winter. Instead, upon their return, the Cree groups who traded at the Bay

> travelled directly to the open grasslands. Here they remained unless adverse weather drove the bison into the adjoining parkland. By the end of January or mid-February, they began a leisurely move to canoe-building sites, which were reached in early April. These sites, located near stands of birch, were adjacent to the forest but within the wintering range of bison (Russell 1991:108).

The location, stability and size of wintering bison herds appears to have been the most important influence on the settlement patterns of Precontact human hunter-gatherers of Western Canada. The need or desire for access to wintering bison compelled the Precontact inhabitants to make settlement choices which seem somewhat irrational to many twentieth-century archaeologists and historians. The importance of various foods to these people must be appreciated to understand better their decision-making processes. The effect of native dietary preferences and restrictions on the subsistence patterns of Precontact hunting and gathering peoples are considered in the next chapter.

Chapter 4 Factors Affecting Subsistence and Settlement Choices

4.1 Introduction

In order to model subsistence and settlement strategies of Precontact individuals, it is necessary to make a number of assumptions about their behaviour. Many of the assumptions common to later subsistence models are explicitly stated by Jochim (1976:10) and summarized below:

1) Economic behaviour is the result of conscious choices.

2) These choices are deliberate rather than opportunistic.

3) The deliberation is rational, based on preferences among consequences.

4) The probability of the outcomes of choices are uncertain and must be estimated.

5) The choices seek to satisfy predetermined aspiration levels, not to maximize any specific measures.

6) The choices will allow or prefer mixed strategy solutions.

7) A desire to limit effort underlies all economic decisions.

While the primary objective of the economic activity is provision of the necessary sustenance and nonfood material needs of the population, a secondary goal is to limit the effort required to procure those resources (Jochim 1976:16-17). Furthermore, good tasting food is sought, with fat content being a strong measure of taste (Jochim 1976:19). Jochim (1976:20) also regards "the desire for variety in the diet" as another goal guiding economic decisions.

While the validity of several of these assumptions is overtly apparent, others may not necessarily be appropriate under all circumstances. Jochim (1976:7) characterizes

subsistence strategies in terms of game theory, concluding that most hunter-gatherer groups adopt strategies which include diversification:

> In general, games in which pure strategies are considered best according to the various criteria are rare, and mixed strategies, when possible, are usually prescribed. The practice of mixed strategies in economic decisions would take the form of more than one activity, simultaneous exploitation of more than one location or region, and sequential changes of activities and locations utilized. Since such practices are seen among all hunter-gatherers, the assumption of mixed-strategy solutions will be used in the construction of the model.

Jochim tests the assumptions of his model against the Round Lake Ojibwa, a modern ethnographic example of forest-adapted hunter-gatherers. The Round Lake Ojibwa exploit moose, beaver, small game and fish throughout the year with the exploitation of one food source increasing when another decreases in availability. As discussed in the previous chapter, bison was the preferred food of plains people so they may have little inclination to make major changes in their diet. Research into human food selection indicates that staple and preferred foods show little decline in palatability over an extended period of time, but people quickly grow tired of eating less desirable foods (Rolls *et al.* 1982:118-119). Rolls *et al.* (1982:119) finds that self-selection of the items to be included in a repetitive diet reduces dissatisfaction with the diet. People consuming favorite foods do not quickly tire of eating them, but they tire of eating lesser preferred food very easily.

More recently, Keene (1985) has developed a mathematical or linear programming model focusing on resource scheduling from a cost-benefit perspective. His assumptions that hunter-gatherer economic activities are organized, planned and directed toward providing the basic nutritive materials necessary for survival are similar to Jochim's, but

Keene (1985:159) also considers the total food and non-food value or *utility* of the resource. Keene suggests that when faced with a choice between two resources of equal utility, the one with the lowest cost, in terms of time investment or risk incurred, will be chosen.

This is similar to Winterhalder's (1987:313-314) optimization principle which states that "human foragers will adopt behaviours that allow them to achieve the highest possible net rate of energy capture *while foraging*." Through his Diet-Breadth Model, Winterhalder (1987:317) predicts that the presence of a resource in an optimal diet does not depend on its abundance; rather its inclusion depends on the rank of the resource and the abundance of items of higher rank. An optimal forager would chose to pursue an item if and only if he/she does not expect, in the same interval of time, to both locate and capture a more valuable item (Winterhalder 1987:317). The utility of an item is also important, being the worth that people attribute either because it is useful or because it has status within sociocultural systems of meaning or exchange (Winterhalder 1987:327). Another prediction Winterhalder (1987:332) makes is that foragers will avoid variance if their current energy budget is positive and seek variance if the budget is negative. Essentially, they will maintain their foraging habits as long as the group's energy or material requirements are being met.

As demonstrated in the preceding chapters, the behaviour of hunter-gatherers on the plains, parkland and boreal forest, as known from historic, ethnographic and archaeological information, is consistent with our current understanding of subsistence behaviour. By using this information in conjunction with subsistence and settlement

modelling principles, the adaptive strategies operating in the study area can be reconstructed. While insights can be gained by examining a problem from a number of theoretical perspectives, optimal foraging models, such as Winterhalder's, are judged to have particular merit for the understanding of Precontact human adaptation in the study area. Environmental models are useful for providing an inventory of exploitable resources in defined catchment areas, but they do not address how foragers decided which resource to use. Jochim's (1976) hunter-gatherer goal model assumes that all resources enter the diet. By contrast, optimal foraging theory provides a framework for modelling the selection of diet items (Bettinger 1980).

Foraging theory simplifies subsistence analysis by addressing broad strategies including diet-breadth (what to eat), patch (where to forage), time allocation (how long to forage), foraging-group size (with whom to forage) and settlement location (where to live) (Smith 1983:626). The selection of dietary items is based on search time, the amount of time it takes to locate one item, and handling time, the amount of time required to capture, prepare and consume the item (Bettinger 1980:208). Handling time varies as a function of the size of the dietary item relative to the size of the consumer so that larger dietary items have lower handling times. If the search time for the dietary item with the lowest handling time is high, the item with the second lowest handling time is added to the diet. Items continue to be added until an equilibrium point is reach where the net rate of return per unit foraging time is maximized (Bettinger 1980; Smith 1983). The inclusion of an item depends only on the abundance of items of lower handling time; it is independent of its own abundance.

This feature of the model is useful for explaining specialized diets and dietary responses to food shortages. Some researchers predict that meat-dependent hunter-gatherers would only occur at high latitudes, such as the Arctic, but Bamforth (1988:6) points out that the plains are similar to the Arctic in that hunter-gatherers are presented with a relative abundance of meat and a relative scarcity of edible plants. While bison were important to people based in the parkland and southern boreal forest, they were central to the lifeways of people following a plains adaptation. Bison were not only the preferred food but they supplied most of the material needs of plains people as well. Alexander Henry the Elder (1969:317-318) observed this about the Assiniboin he visited in February 1776:

> The wild ox alone supplies them with everything they are accustomed to want. The hide of this animal, when dressed, furnishes soft clothing for the women; and, dressed with hair on, it clothes the men. The flesh feeds them; sinew afford them bow-strings; and even the paunch, as we have seen, provides them with that important utensil, the kettle. The amazing numbers of these animals prevent all fear of want; a fear which is incessantly present to the Indians of the North.

The impact of the high utility of bison on the behaviour of hunter-gatherers can be considered in optimal foraging models.

4.2 Native Dietary Preferences

A number of criteria, including availablity, abundance, and fat content, have been used by archaeologists to hypothesize which foods were eaten by Precontact Native people at different times of the year. These criteria are offered as an objective or rational means of ranking the importance of certain foods; however, historic records provide evidence that preference may have played a very important role in food selection. Some

foods were sought, even when they were scare; others were shunned, even when they were abundant. This information must be considered in the development of subsistence models.

4.2.1 Bison

While all acknowledge that other foods were exploited, bison was always identified as the single most important food of Native groups who inhabited the plains and parkland in both early historic and ethnographic accounts (Ewers 1955; Lowie 1954; Mandelbaum 1979; Wissler 1912; Umfreville 1954; Flannery 1953; Kroeber 1908; Morgan 1959). Near modern Red Deer, the Blood chief's response to Henday (1973:32) indicated that young men adapted to a bison economy would be unable to travel to the fort to trade for furs:

> But he answered , it was far off, & they could not live without Buffalo flesh; and that they could not leave their horses &c: and many other obstacles,though all might be got over if they were acquainted with a Canoe, and could eat Fish, which they never do. The Chief further said they never want food, as they followed the Buffalo & killed them with Bows and Arrows; and he was informed the Natives that frequented the Settlements, were sometimes starved on their journey. Such remarks I thought exceedingly true (Henday 1973:32).

Umfreville (1954:104) reported that the Blackfoot, Piegan and Blood Indians who frequented his establishment in the 1780's did not eat waterfowl, amphibians or fish, only bison, deer and vegetables. Flannery (1953) wrote the Gros Ventre of Montana considered bison flesh, both fresh and dried, as "real food", and preferred it to all others. Indian men were said to eat 8-10 lbs (3.6-4.5 kg) of bison each day (Ewers 1968:170). Bison was also an important food of groups from the forest edge and Rocky Mountains (Hurt 1974:33; Thompson 1962:42, Lowie 1909:184).

Not only were the early Postcontact peoples partial to bison, but fat cows. Cow bison were best in August when they returned from the southern grasslands (Thompson 1962:54), but they were almost universally preferred to bulls year-round. Henry (1992:372) noted the Assiniboin left small openings in their pounds so dogs could get in to feed upon the carcasses of the bulls, generally left there as useless. On 21 December 1809 near Fort Vermilion, Henry (1988:422) described animals left inside a Blackfoot pound from previous use, "The Bulls were mostly all entire, and none but good Cows were cut up." When James Tanner (1956:212), who grew up with Native people, killed a large number of fat bison, he dried only the choice parts.

Bulls were usually tough and lean compared to cows. According to David Thompson (1962:47-48), bull meat was eaten when necessary:

> ...but their flesh when boiled is so very tough that although our teeth were in good order, and well inclined to do their duty from having had twenty four hours rest, had we masticated the meat by medical rules it would have taken three hours to make our supper. As it was we gave each mouthful two or three hearty nips and swallowed it down. The flesh of Bulls in their best state is only fit to be dried and made into beat meat which is frequently done.

Others considered bull bison meat to be superior to cow in the early part of July before the rut (Henry 1988:206).

Bison were used throughout the year, including late winter and spring. In late winter when adult bison were becoming fat depleted, pregnant females were killed for the foetal bison they carried. On 4 February 1793, Fidler crossed the Bow River just below the mouth of the Highwood just southeast of Calgary and wrote:

Men running the Buffalo & killed a few. The Calves in the Womb are now

> all well covered with hair. These calves all Indians are remarkably fond of even when not more than the size of a Quart pot they eat them. The greater part of the Cows the Indians now kill is merely for nothing else but for the calf (MacGregor 1966:81).

On 24 April 1769, near the elbow of the North Saskatchewan River west of Saskatoon, William Pink witnessed a bison pound operated by 31 tents of Assiniboin (Russell 1991:101-102). At this time of year the full-term foetal bison and young calves were probably the object of the hunt.

The amount of fat meat consumed by Natives was considered excessive by European standards. Mackenzie (1927:101) believed that the Knisteneaux [Cree] got pains in their chest from their "immoderate indulgence in fat meat at their feasts, particularly when they have been preceded by long fasting." It is well documented that melted fat, and sometimes berries, were added to dried meat in the manufacture of pemmican (Harmon 1957:27; Lowie 1954:24; Mandelbaum 1979:58; Thompson 1962:51; Wissler 1912:26). Harmon (1957:27) indicated that, when stored in bison hide bags and kept in a dry place, pemmican could be preserved for several years; in a damp place it became musty.

4.2.2 Dogs and Other Canids

According to Regina Flannery (1953:59), puppy flesh rated second only to bison on the scale of Gros Ventre favourite foods. Full grown dogs were eaten in times of famine. Lewis Henry Morgan (1959:154) said the Dakota have large numbers of "wolf dogs" which are often killed and roasted. Harmon (1957:29) noted:

> Our People killed a Dog to eat, the flesh of which they say is excellent, but they are of a different species than those I have seen in the Civilized part of

> the World, these have a greater resemblance to Wolves, and it is said that their flesh has a different flavour.

Henry (1992:488) remarked, "My people prefer purchasing Fat Dogs from the Indians to eat than to live upon lean Buffalo Meat." Dog eating was reported among many Native groups in the historic period, particularly on ceremonial occasions (Snyder 1991:360).

Not everyone would eat dog flesh. The Ojibwa "mother" of John Tanner, Net-no-kwa, fed dog flesh to her children but would not eat it herself (Tanner 1956:58). When it scared off the moose he was stalking, Tanner killed his dog and fed it to his children (Tanner 1956:202). Thompson (1962:105) and Mackenzie (1927:121) both reported the Chipewyan or Dene would not eat dog flesh and despised those who did, the Cree and French Canadians. Although full grown wolves and coyotes were not consumed, the Gros Ventre ate the young of these animals (Flannery 1953:59). Mackenzie (1927:70) wrote that the flesh of wolves was not eaten but a tallow was produced from their fat.

4.2.3 Moose, Deer and Antelope

Whereas bison were migratory animals, other ungulates were available in parkland environments throughout the year. For example, while travelling on the Red River south of the Forks, Henry (1988:26) mentioned moose and deer were abundant year round but bison only came to the area to shelter themselves from severe storms and cold weather. In spite of availability, elk, deer and moose were regularly exploited by both Natives and traders only in the absence of bison. William Tomison, George Sutherland and James Bird, traders at Edmonton House from 1797-1800, all noted that moose and deer were hunted in the absence of bison (Johnson 1967). At Fort Alexandria on 1 June 1801,

Harmon (1957:48) noted his hunters were after moose and deer because bison had left the area. Henry (1992:402-418) and his people at Fort Vermilion utilized moose, red deer and other food resources in the fall of 1809 until the bison arrived. As soon as bison became available, moose and deer were quickly abandoned.

In apparent contraction, Thompson (1962:63) regarded moose to be nutritionally superior to other meat, suggesting that five pounds of high quality moose was equal in food value to seven pounds of other meats. Umfreville (1954:83) and Harmon (1957:42) both indicated that moose tasted better than other meat, including bison. Like bull bison, bull moose was best in early July before rutting season (Henry 1992:453). "Fallow deer" and "cabbrie" (white-tailed deer and antelope) were also considered tolerable good eating in the summer when they were fat (Henry 1992:459).

Elk, called red deer, was not considered, by traders at least, as palatable as moose because the fat turned cold and hardened very quickly (Umfreville 1954:83; Thompson 1962:53). Umfreville (1954:84) said its fat "turns cold so very fast, that a person must eat it the instant it is taken from the fire; and even then the mouth is sometimes lined with a grease of the consistence of tallow." Thompson (1962:42) implied that bison and elk held equal status to the Indians in "the Saskatchewan", so these opinions may reflect a purely European taste bias.

Bison and dogs were preferred by Gros Ventre, however,:

> The flesh and other edible parts of most animals hunted by the Gros Ventre were appreciated if there happened to be a dearth of buffalo, or as a welcome change during the winter months from the dried buffalo meat (Flannery 1953:59).

Elk, deer and antelope rated equally as third on their list of favourite foods (Flannery 1953:59). Mandelbaum (1979:68) indicated, although moose and elk were abundant, the Plains Cree did not hunt them extensively. As well, the hunters did not want to leave the large encampments alone or in small groups to hunt these animals in the hills. More hunting skill was required to kill these animals, whereas bison were easy, often abundant prey (Mandelbaum 1979:68). This is supported by several entries in Harmon's journals from Fort Alexandria and Bird Mountain. Harmon's people often went hungry because his hunters were unable to successfully kill either moose or elk (Harmon 1957).

The effort required for their procurement may have been a major factor in reducing the economic importance of these animals. Among them, only antelope are gregarious. Antelope could be hunted communally but because of their relatively small body and herd size they were probably only sought in the absence of bison.

4.2.4 Bear

From historic accounts, bear flesh did not appear to have been appreciated as much as bear grease. Before reaching the location for his new post in the fall of 1800, Henry (1988:45) reported the Indians with him wanted to stop, kill a few bears and make "oil":

> The fat of the Bear whilst in the raw state will not keep many days particularly when the weather is sultry, but will soon turn rancid and spoil. But when melted down and properly taken care of [it] will keep good and sweet at any season of the year (Henry 1988:54).

Tanner (1956:285) indicated that at war feasts an entire animal was consumed and, "if it is in their power, they have a large bowl of bear's grease standing by, which they drink in

place of water." The value of bear grease is reiterated by Flannery (1957) for the Gros Ventre, who hunted grizzly and black bears opportunistically. The flesh of the animals was eaten fresh but only the grease was stored (Flannery 1953:59). The Indians around the Pembina posts hunted both common and grizzly bears denned along river banks, in hollow trees and in thickets over the winter (Henry 1988:99). Around Fort Vermilion, bears, like moose and elk, were procured only in the absence of bison (Henry 1992:416). Thompson (1962:95) wrote that the flesh of a bear feeding on roots or berries was good, but it became disagreeable when the bear ate fish.

4.2.5 Small Mammals

Although a wide variety of small mammals were said to have been exploited, it is difficult to assess their relative dietary importance. The Gros Ventre rated beaver fourth on the list of preferred foods (Flannery 1953:59). Thompson (1962:152) reported that beaver flesh was edible, but fat and oily; the tail, however, was a delicacy. Other animals such as prairie-dogs, gophers, rabbits, badger, porcupine, lynx, kit-fox, marten, skunk, squirrel, fisher, mink, muskrat, otter were eaten, at least by some groups, when necessary (Mandelbaum 1979:70; Thompson 1962:67-69; Flannery 1953:59). The Indians around the Pembina posts hunted raccoons in hollow trees over the winter by smoking them out (Henry 1988:99). These animals were said to be excellent eating when stripped of fat and roasted over a fire (Henry 1988:73). Thompson (1962:187) attributed the fatness of these animals to their diet of nuts.

4.2.6 Fish

As indicated earlier, a Blood Chief told Henday that his people never eat fish

(Henday 1973:32). Umfreville (1954:104) reported the Blackfoot, Peigan and Blood Indians he knew denied ever eating fish. Umfreville's post was on the North Saskatchewan River in a region where fish was abundant:

> but the natives seldom or never look at them, and the greater part of those Indians who came to our settlements to trade, will neither eat fish, water-fowl, nor any amphibious animal (Umfreville 1954:77).

Kroeber (1908:149) indicated only Gros Ventre children ever caught fish and this was for amusement. The Plains Cree, who recently abandoned their forest adaptation, regarded fishing as a sport even though the resource was an important dietary supplement:

> ...an ample supply of fish enabled fairly large groups to gather at seasons when they otherwise would have had to disperse over the countryside in search of game. Hence fish not only added to the fare but also expanded the size of the camps and thus enlarged social opportunities (Mandelbaum 1979:71).

Although there are several historically documented denials, Lowie (1954:17) reported Plains groups resorted to fishing when groups were short of meat. The Cree used weirs and the Blackfoot used crude basket traps.

The availability of fish to Precontact peoples in winter is disputed (Syms 1977:31), but there is some evidence that fish were exploited at this time of the year. Tanner (1956) noted that forest-adapted Cree fished during the winter. Their camp was situated on Elk (Red Deer?) River, located between the Assiniboine and Saskatchewan Rivers six days travel north by horse from the Souris River. A woman there prepared a meal which Tanner and his group was not familiar with:

> When the food was placed before us, we found it consisted of little fishes, scarce an inch long, and all the same size. When put into the kettle, they were in large masses, frozen together. These little fishes, with the taking

> and eating of which we afterwards became familiar, are found in small holes which remain open in the shallow ponds, crowded together in such numbers that one may scoop up hundreds of them at once with the hands (Tanner 1956:73).

Mandelbaum (1979:71) indicated that almost all fishing among the Plains Cree was done in the winter and early spring. In winter, fish were attracted to open places in the river ice with torches and speared. Holes were not chopped in the ice, instead they utilized openings made by inflowing springs (Mandelbaum 1979:73-74). In spring, weirs were constructed but no serious effort was made to catch fish in summer (Mandelbaum 1979:71).

Several accounts exist of Native sturgeon fishing on the Red and Assiniboine Rivers in modern Manitoba, North Dakota and Minnesota. Tanner (1956:37) recalled killing sturgeon at an Assiniboin and Cree camp of 150 lodges near the junction of the Assiniboine and Little Saskatchewan Rivers. In June 1805, near Pine Fort on the Assiniboine River, sturgeon were driven onto sand bars with canoes; Indians came to the area annually to catch and dry sturgeon (Harmon 1957:90). In late April 1803, the Indians built a sturgeon weir on the Pembina River in eastern North Dakota (Henry 1988:140). In late summer of 1861, Morgan (1959) described "half-breed Crees" on Red Lake River, Minnesota, catching sturgeon in nets. The flesh was dried and smoked simultaneously; oil was fried out of the fattest parts of the fish and put in pails (Morgan 1959:130).

In general, groups who lived in more forested environments, or traditionally had a forest-adaptation, such as the Ojibwa in early historic Manitoba, exploited fish on a regular basis. But Thompson (1962:105) suggested some forest-dwellers, such as the

Dene, turned to fish only when deer were scarce. Plains-adapted groups who maintained an almost exclusive red meat diet, rarely, if ever, fished.

4.2.7 Waterfowl and Other Birds

There is considerable documentation of traders exploiting waterfowl and other birds and of Natives bringing birds to hungry traders, especially at Cumberland House (Tyrrell 1968). Native exploitation of this resource for their own use is less common. As mentioned in the previous section, the Blackfoot, Peigan and Blood deny ever eating waterfowl. The Gros Ventre considered duck, goose, grouse, prairie-chicken, and curlew and their eggs edible (Flannery 1954:59; Kroeber 1908:149). In addition to those mentioned above, the Plains Cree ate swans, water herons, wild turkeys, partridges, magpies, chicken and sparrow hawks, owls, eagles and ospreys, young crows and young ravens (Mandelbaum 1979:69-70). Tanner (1956:76) "killed birds, ducks and geese" in the spring while he was making maple sugar in Western Manitoba.

Some types of birds were procured individually but mass kills of waterfowl were possible during the summer moulting season. Waterfowl was especially important when alternative food sources were unavailable. In 1806 around Portage La Prairie, when people could "scarcely find food sufficient for their families," moulting birds were killed on Lake Manitoba (Henry 1988:195):

> Here the Swans and other[s] shed their feathers at which season the Indians destroy great numbers by pursuing them in Canoes and killing them with sticks. Eggs of all sorts they also collect in great abundance, even Canoe loads [Henry 1988:195].

Thompson (1962:63) indicated swans were hunted at night using torches to attract the

birds to the canoes. Umfreville (1954:88) thought waterfowl was not highly esteemed because of the smallness of the quarry:

> The country being so well stored with animals of the larger kind, to supply its inhabitants with food, it is but seldom the feathered game are disturbed.

From the historic descriptions it is clear that forest-adapted peoples with canoes could exploit this resource effectively. Although there is ethnographic evidence that some plains people hunted waterfowl, it was probably not an economically important food.

4.2.8 Summary

While a wide variety of foods were available, they were not ranked as equal in terms of desirability. There were important differences in food preferences between plains and forest groups. Bison was the most important food among plains-adapted peoples, followed by dogs; fish were avoided. Forest-adapted peoples readily exploited spawning fish but refused to eat dogs. Deer, elk, antelope and moose were regarded favourably, but the solitary habits of deer, elk and moose made them more difficult to hunt and reduced their economic importance. The relatively small size of antelope and their herds probably made them less attractive than bison. These food preferences are considered in the settlement-subsistence strategies, which are presented in the following chapter.

4.3 Fish Aversion as a Subsistence Consideration

According to the subsistence models discussed above, the Late Precontact Period hunter-gatherers of Western Canada are expected to have followed a mixed strategy, rather than focus on one type of food. The desire for variety of the diet and high fat content are considered to be important factors in food selection. When abundant, low

prestige food items should replace higher prestige items, especially if the handling time of the low prestige food items is lower. In spite of this, there is little indication that plains-adapted people exploited fish, even during spring spawning season when they were abundant and bison were fat-depleted.

Fish avoidance is ubiquitous to the extent that little or no use of fish was considered a general culture trait of indigenous people adapted to nomadic life on the plains (Wissler 1950:220-222; Lowie 1967:490; Denig 1961:48-49). Kroeber (1908:149) indicated only the children of the Gros Ventre ever caught fish and this was for amusement. In his study of the Crow, Lowie (1935:72) found no evidence that these people ever ate fish. Fish were eaten by Comanche peoples only when food was very scarce (Wallace 1952; Lee 1957; Gilles 1974); like the plains-adapted Apache, the eating of fish was forbidden among the Comanche. The Kiowas also followed a plains-adapted hunting and gathering economy and did not eat fish (Mayhall 1971). As discussed in the previous section, a Blood chief cited their inability to eat fish was one reason why his people could not travel through the forests to the trading posts on Hudson Bay (Henday 1973:32). Edward Umfreville (1954:104) reported the Blackfoot, Piegan and Blood Indians he encountered denied ever eating fish even though they were abundant.

The emphasis on hunting together with the absence of fishing from the subsistence repertoire of people adapted to life on the Great Plains of North America is rather unexpected. Fishing is the dominant mode of subsistence in cool to cold latitudes, 40-59° from the equator; hunting is the dominant mode of subsistence only in the Arctic, at latitudes of 60° or more (Lee 1968:42). Furthermore, the large ungulates which inhabit

the region lose a large proportion of their body fat during the course of the winter. By the spring the animals are fat-depleted and their flesh is extremely lean.

The consequences of eating lean meat can be severe because high amounts of energy are required in order to digest it. Consumers experience a substantial increase in their metabolic rate so the caloric requirements of digestion are very high (Speth and Spielmann 1983). As a result, ingested nutrients are used directly to meet the immediate energy needs related to digestion while the consumer's body protein is not replenished. In extreme cases, a consumer can actually starve to death while subsisting on lean meat, a phenomenon referred to as "rabbit starvation." If lean meat is accompanied by other foods, the meat can be digested without depleting the consumer's energy. Fat- and , especially, carbohydrate-rich foods have a "protein-sparing effect" in that they fill the body's energy needs for digestion so ingested amino acids are used to replenish body protein (Speth and Spielmann 1983). For this reason, Speth and Spielmann (1983) predict that spawning fish would be used in the late winter and early spring because they have a high polyunsaturated fat content and are available as other food sources are fat-depleted. In apparent contradiction to the principles of optimal foraging and in spite of the apparent advantages of utilizing this resource, plains-adapted people apparently avoided the use of fish as food. Other selection factors, such as desire for dietary diversity and the relative abundance of the resource in the spring had little influence on the behaviour of plains-adapted peoples.

The dependence on bison for food is considered a general culture trait of the indigenous, nomadic inhabitants of the Great Plains. The indigenous people of the Great

Plains did not eat lean meat on its own. Lean animals killed in a hunt were either left for the dogs or the meat was dried (Thompson 1962:47-48; Henry 1988:422; Henry 1992:372). Dried meat was either served with berries or mixed with melted fat, and sometimes berries, in the manufacture of pemmican (Harmon 1957; Lowie 1954; Mandelbaum 1979; Thompson 1962; Wissler 1912). The addition of fat and carbohydrates made the meat more palatable, digestible and easy to preserve. Pemmican could be stored for up to two years if kept free from moisture (Harmon 1957). By utilizing foetal/newborn bison and stored food, the hunter-gatherers on the Great Plains could subsist on bison throughout the year without suffering from the effects of eating lean meat. If for some reason bison were unavailable or unattractive, other foods were added to the diet. Plains-adapted people are known to have eaten dogs, deer, elk, antelope, small mammals and some species of birds but rarely, if ever, did they fish.

Explanations offered for the rejection of fish as food in different cultures, commonly involve religious, sensory affective and economic factors. Simoons (1974) attributes most fish avoidance in India to the general concept of non-violence to sentient beings; fishing and the consumption of fish are considered low caste activities. Dietary needs, however, supersede religious convictions in northern and eastern parts of the country where even members of high Brahmin castes eat fish. Water and all water creatures, are considered sacred by the Navajo, Zuni and Apache, indigenous tribes in the American Southwest and are, therefore, not eaten (Schwabe 1988). Contempt for those who eat fish dates back almost 3000 years in Africa (Simoons 1974:185). Fish were likened to snakes and considered inedible, either because they were sacred or because they

were "filthy and smelly" (Schwabe 1988). Schwabe (1988:267) reports, "These prejudices are unusually common among nomadic peoples, and cattle keeping and fishing are seldom found to go hand in hand", and proposed that the origin of some fish avoidances in Africa relate to the rapid spoilage of fish in warm climates and the associated odours.

Simoons (1974) cited historical evidence that links fish avoidance in Eurasia to the nomadic lifestyle of their ancestors. It was argued on linguistic grounds that fish were not used as food in the grasslands of Eurasia, considered to be the probable ancient Indo-European homeland (Simoons 1974:186). Turkic people of nomadic tradition scorned and avoided the use of fish. Although they were available in local rivers, tribesmen in Pakistan and many parts of Afghanistan did not eat fish. Simoons (1974:188) remarked:

> The occurrence of fish avoidance among such linguistically-diverse peoples may derive from various factors, but to me the most striking one is the common ecological experience, as nomads or semi-nomads, that so many of the groups shared.

He (1974:197) speculated that needs of nomadic life were not compatible with fishing and, because the nomads' herds provided an adequate supply of animal protein, it was not necessary to eat fish.

Ethnohistorical evidence from the grasslands of Western Canada and the United States seems to support the hypothesis that fish avoidance is linked to nomadic economies. Simoon's (1974) hypothesis does not, however, explain the behavior of nomadic groups living in more wooded areas on the periphery of the plains, where fish avoidance was less common. The Cree who occupied central Saskatchewan are referred to as the Plains Cree, although they lived in a parkland environment (Russell 1991). The resource was an

important dietary supplement:

> ...an ample supply of fish enabled fairly large groups to gather at seasons when they otherwise would have had to disperse over the countryside in search of game. Hence fish not only added to the fare but also expanded the size of the camps and thus enlarged social opportunities (Mandelbaum 1979:71).

Denig (1961:117-118) indicated the Cree spent much of the summer fishing and hunting waterfowl. The Assiniboin are known to have exploited fish and established fishing camps with the Cree in western Manitoba (Ray 1974; Harmon 1957:90; Tanner 1956:37). Fish remained an important dietary component of the Plains Ojibwa or Bungi, who moved from the forests into the parkland of eastern Manitoba in the latter part of the 1700s (Howard 1977). Similarly, the Flatheads of western Montana and the Northern Shoshone, who lived along the Rocky Mountains from Montana to Nevada, hunted bison on the plains but also fished (Fahley 1974; Lowie 1909).

Unlike the grasslands where massive herds of bison were found, the large ungulates of the boreal forest, such as moose and deer, are solitary or form only small groups. As a result, hunter-gatherers in the forest typically rely on a combination of resources including moose, deer, small mammals, waterfowl and fish. This diffused hunting and fishing economy has existed in the forest for at least 9000 years (Dawson 1983:64). The use of fish by hunting and gathering groups which inhabited the parkland and southern boreal forest demonstrates that its avoidance is not necessarily associated with nomadic economies.

According to Rozin (1984:596), the three basic reasons for accepting or rejecting food are 1) sensory affective factors including the texture, odour or appearance of the

food, 2) anticipated consequences, where a food is accepted or rejected on the basis of expected effect, be it physical, ideological or social, and 3) ideational factors, where a food is accepted or rejected primarily on the knowledge of what it consists, or from whence it came.

While biological explanations are more likely for universal features of food choice, there are few examples of food aversions that have an identifiable biological basis (Rozin 1984:591). One of the best known is lactose intolerance among peoples without a history of pastoralism and dairying (Simoons 1982). In areas where the prevalence of lactose malabsorption is high, rates of milk consumption are very low. The symptoms of lactose malabsorption includes stomach gas, intestinal discomfort and, in some cases, cramps, diarrhea and vomiting. Considerable evidence indicates that when the ingestion of food is followed by nausea or vomiting, strong aversions to that food develop (Barker 1982; Rozin 1984).

In the case of fish avoidance, the one factor common to all cultures which avoid fish is that their diets are dominated by red meat. If people accustomed to red meat diets anticipated negative physical effects after consuming fish, strong aversions to fish may develop. The major differences between red meat and fish is their fat content. The eighteenth and nineteenth-century accounts of fur traders and travellers provide evidence that people accustomed to diets which emphasized red meat experienced symptoms typical of lipid malabsorption when they consumed fish. Alexander Henry the Younger (1988:157-158), a fur trader, recorded this annual event at his posts, located along the Pembina River in modern northeastern North Dakota:

> ...My people are now all unwell, as usual every spring, from the sudden change of diet, from flesh to fat Sturgeon, they are troubled with a continual dysentary that reduces them very much and makes them weak and faint. Although they are most extraordinary gormandizers, the Sturgeon oil is too much for them. We now take a number of very large fat Piccaneau in our Sturgeon nets. They are excellent eating but only of too oily a nature, and tend much to increase my peoples decrease.

After breaking his leg, David Thompson (1962:55) was sent from the plains to recuperate at Cumberland House, located in the boreal forest of northeastern Saskatchewan. The move was associated with the change from a diet consisting primarily of red meat to one consisting primarily of fish. Thompson found he could not eat the available food, "the fish caught were sturgeon of excellent quality but too rich for my low state of health and I became emaciated till the berries became ripe."

William Clark, of the Lewis and Clark Expedition, and his party subsisted primarily on berries and horses on their return trip from the Pacific coast (Jackson 1962:328). In a letter to his brother, Clark reported, that while crossing the Idaho mountains, his party encountered the Pallotepallors who:

> ...furnished us with an abundance of roots and dryed salmon the food to which they were accustomed we found that we could not subsist on those articles and almost all of us grew sick on eating them. We were obliged therefore to have recourse to the flesh of horses and dogs as food to supply the dificiency of our guns which produced but little meat as game was scarce in the vicinity of our camp... (Jackson 1962:328-329).

These historic examples show that the sudden change from a regular red meat diet to one of fish can produce illness. Both Henry and Thompson identify the introduction of fat-rich fish into their diets as the source of the problem. This is quite possible as the diarrhea and loss of energy Henry described are symptoms of lipid malabsorption. The

digestive systems of people accustomed to a diet of predominantly lean red meat may have been unable to adjust quickly enough to process fat-rich fish, resulting in lipid malabsorption (B. McDonald, personal communication). Gross (1949) undertook ethnographic fieldwork among the Wind River Arapaho in the late 1940s. He (1949:83) reported that fish eating was slowly becoming more common among the Arapaho, although people indicated they did not like fish. It is possible that lipid malabsorption was avoided by the slow introduction of fish into the diet. A sudden dietary switch from lean red meat to fat-rich fish would be avoided, however.

4.4 Settlement Considerations

The economic importance of bison, in terms of both food and nonfood value, would have attracted hunter-gatherers from all vegetation regions to where they would have access to bison over the winter; historic accounts and the archaeological record show this area was the open grasslands. This wintering behaviour is not predicted for bison from an ecological perspective; the availability of superior forage should have attracted herds deep into the parkland, up to and including the outer periphery of the Aspen Grove region (Gordon 1979; Morgan 1979,1980). Evidence supporting this movement of bison can not be found in the records of fur trading establishments situated in the parkland. Observations of wintering bison reaching forts located in the parkland are rare; vast herds of bison were instead found out on the open plains. One possible explanation for this behaviour may be connected to snow accumulations.

The climate and the physiography of southern Alberta make it ideal for supporting large populations of wintering bison. During the winter, the treeless plains provide little in

terms of shelter from the cold winds or provision of wood for fuel, but the grasslands of Southwestern Saskatchewan, Southern Alberta and the Foothills provide favourable winter conditions for grazing animals. These areas, plus the interior of British Columbia, are considered the only parts of Canada with climates that permit winter grazing of range cattle (MacEwan and Ewen 1952:258). Chinook winds provide relief from the cold and blow snow off the grasslands, often leaving only a thin covering on the prairie (Gould 1978:63). Levels of annual precipitation are higher in the parkland and the vegetation breaks up the wind enabling the snow to accumulate. For a grazing animal, the increased energy necessary to nuzzle or paw down through the snow lessens the attractiveness of superior forage (Vallentine 1990:357). Roe (1951:99) presented one account where bison became so emaciated when grazing through snow two or three feet deep for several months that they lost hair and scabs formed on their hides. When snow accumulations are very high, it can become a deadly trap for the bison. While based in Fort Vermilion, Henry (1992:438) recorded that more than sixty bison, being unable to stand up again, were found laying dead in the deep snow. In a normal winter, the upper limit of stable, large populations of wintering bison was the lower edge of the parkland. If the weather was severe, more bison moved from the open plains to sheltered river valleys and the parkland. From Fidler's record of the winter of 1801-1802, it is clear that large aggregates of bison remained far out on the plains throughout even extremely harsh winters.

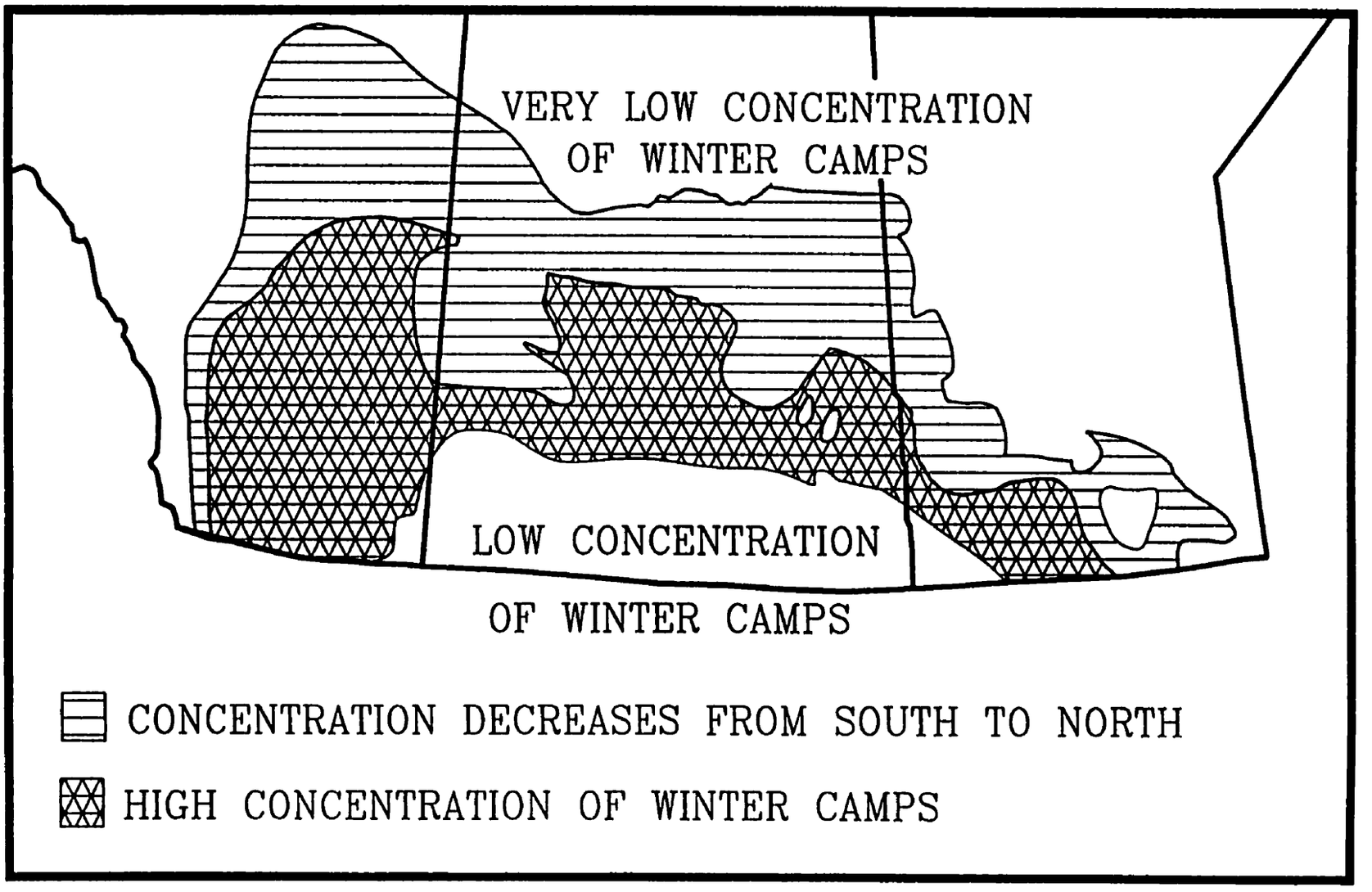
Vickers' (1991) discussion of seasonal rounds highlighted the significance of southern Alberta physiography, consisting of plains highly dissected by the many streams and rivers which flow east from the Rocky Mountains. For these reasons, most of the

southern Alberta grasslands would be suitable for wintering populations of bison and people. The shortage of wood for fuel was not necessarily a major impediment to wintering on the plains. At the time of Palliser's expedition, trees and shrubs occurred in a few isolated patches on the bottom of river valleys on the plains yet there are numerous historic accounts of winter camps in the area. Bison chips were probably heavily exploited as fuel in this area. Experiments show that well-seasoned bison chips burn hotter than wood; even chips of inferior quality can produce temperatures which exceed 1000°C (Wright 1992).

The parkland belt extends from western Alberta to eastern Manitoba with the density of treed areas increasing northward towards the forest edge (Meyer and Epp 1990). While bison were found in abundance on the northern grasslands in an average winter, the numbers of wintering bison declined as one proceeded north. The upper boundary of the parkland is considered the limit for wintering bison although bison may have continued further north along river valleys (Hind 1971 II:108-109). Animals would only reach or extend outside of this upper boundary under extremely harsh winter conditions. The extremely dense vegetation from the Assiniboine River between Portage la Prairie and Winnipeg south to La Salle River, however, may have restricted any wintering bison in this area of Manitoba to river valleys.

The distribution of wintering bison is considered to be the single-most important factor affecting the location of winter camps. If this assumption is valid, the distribution of Late Precontact Period winter camps will mirror that of the bison. As shown in Figure 5, the highest concentration of winter camps are expected to be found in the northern

Figure 5. Hypothesized distribution of winter camps.



grasslands. The number of winter sites would decrease northward from the grassland-parkland transition zone to the forest edge. The decision to winter on the plains can be seen as one of risk balancing; there were hazards associated with camping out on the open plains in winter. Henry the Elder (1969:283) indicated that entire families occasionally died as the result of being buried by snow driven by the wind. On 27 January 1802, Fidler (1967:308-309) described an extremely severe winter storm which lasted over a day; he claimed it was the worst storm either he, after 13 years in the region, or an old Indian at the fort had ever experienced. As a result of the storm, two French Canadians froze their feet, two Fall Indians out trapping froze to death, and those at the Fall Indian camp also suffered:

> ...all their tents was blown over and several of their children was very near perishing through cold; they could not even offer to put up their tents again until the storm was over; they could not make any fire... (Fidler 1967:309).

Although the storm produced serious hardships for the Natives who camped in the area, a storm of such magnitude was by no means a regular occurrence, it was a rare event.

Gould (1978:63-73) reports that after ten years of good weather, ranchers in southern Alberta were unprepared for the severe winter of 1886-1887 which resulted in the death of thousands of cattle. The harsh winters of 1906-1907 and 1916-1917 and major blizzards in 1938 and 1967 also had devastating results for the cattle industry. Over a 100 year period, five climatic episodes are remembered as being terribly difficult. The frequency of fur traders at posts situated in the parklands lamenting that bison were far out in the open grasslands is considerably higher. Moodie and Ray (1976) provide substantial evidence that mild winters, heavy snowfall, fires and hunting could all result in a shortage

of bison in the parkland and hardship for those who wintered in the more wooded areas. To Precontact hunter-gatherers, the risk of a shortage of bison in the parklands may have been considered higher than the risk of enduring a harsh winter on the plains.

From a cultural materialist perspective, the decision of hunter-gatherers to remain in or move to the margins of the grasslands to exploit concentrations of bison is consistent with Harris' (1979) principal of infrastructural determinism. The infrastructure is the means by which culture and nature interact, primarily through subsistence-related activities (mode of production) and population management (mode of reproduction). In short, Harris (1979) argues that the requirements of the observable modes of production and reproduction will largely, but not necessarily exclusively, determine the observable domestic and political economy which in turn largely, but not necessarily exclusively, determine the observable behavioral and mental superstructure (myths, philosophies, art, epistemology). The requirements of subsistence, various hunting strategies and tool kits, the hunter-gatherer's understanding of seasonal bison movements and patterns of plant use are all within the realm of mode of production. The need for members of a small band to find mates from outside, fluidity in band size and composition, population control and the care of infants and elders relate to the mode of reproduction. Even the demographic requirements associated with modes of production may be included.

Bison was a favoured food of the hunter-gatherers in the study area as well as an item with a very high non-food utility. The expectation of encountering wintering bison compelled bands of mobile hunter-gatherers to remain on or close to the northern plains. Reher and Frison (1980) suggest that the success of communal bison hunts depends on the

density of the animals; in areas where bison populations are very low these hunts are not feasible. The concentration of wintering bison on the northern plains was high enough to enable the implementation of communal hunting techniques. Arthur (1975:95-118) presents a detailed arguement which clearly shows that winter was the main season for communal bison hunting among nomadic groups of Western Canada during the Early Postcontact Period. The fall was not the season of the hunt, but the time to repair the pounds for winter use (Arthur 1975:101). Kidd (1986:101) suggests that individual stalking of bison was one of the techniques employed during the summer; in winter, pounding bison was almost the exclusive method of hunting. When horses became more widely available, intensive hunting was conducted primarily during the spring and fall; as the numbers of bison declined, the use of bison drives was abandoned. The introduction of the horse initiated a fundamental shift in the mode of production of these mobile groups. Observations of hunting practises made at the time of earliest European contact, when horses were scarce or not available, more closely reflect the conditions which existed during the Late Precontact Period.

The operation of the communal hunts required large numbers of participants, including women and children. As mentioned in the previous chapter, extremely large winter camps consisting of several hundred individuals were observed. Successful mass kills of bison provided enough food to more than adequately supply these camps. Lean females and bulls taken in the course of the hunt were left for the dogs. The large population aggregations facilitated intermarriage between bands. The high protein, low carbohydrate diet of these big game hunter-gatherers even prolonged the effectiveness of

the lactation method of birth control by suppressing postnatal ovulation (Harris 1979:82). By controlling birth spacing, the need for abortion or infanticide to restrict population growth was reduced or eliminated so the sex ratios tended to be more balanced. Balanced sex ratios ensured an adequate supply of marriage partners. The requirements of the modes of both production and reproduction were satisified and this had a determining effect on aspects of structure and superstructure.

The cooperation between bands and the formations of kinship ties through marriage influenced the structure of the social group, i.e. the domestic and political economy. Cooperation engendered intergroup solidarity; trading partners and political allies were established. The involvement of men, women and children in the communal hunt and the sharing of the proceeds reenforceed the egalitarian nature of the social group. The sharing of rituals and myths, the preparation for and conduct of ceremonies at this time enhanced the behavioral superstructure of the social group.

4.5 Summary

The apparent settlement and subsistence choices of the Late Precontact and Early Postcontact Period hunter-gatherers, at first glance, seem somewhat irrational. On closer scrutiny, however, the basis for these decisions can be understood. According to historic and ethnographic accounts, adult and foetal bison were favourite foods of plains-adapted peoples, followed by dogs, deer, elk and moose; fish was rarely, if ever, eaten. In addition, bison provided the raw material for clothing, shelter and tools so it had a high utility index. Studies of food choice do not support the assertion that mixed strategies and diet diversity are necessarily important considerations; rather, staple or preferred foods

can be eaten and enjoyed for an extended period of time. If either adult or foetal bison were readily available, there would be very little incentive for plains-adapted people to select less desirable foods. An abundance of spawning fish in the rivers in spring would not be a strong attraction. If a shortage of bison occurred, dogs, elk, deer and moose would be sought. Furthermore, if these individuals even attempted a sudden dietary switch from bison to fish, they may experience diarrhea and loss of strength, the symptoms of fat malabsorption. In order to ensure their availability, plains-adapted people formed winter camps in areas with the highest bison concentration.

The numbers of bison reaching the parkland depended upon the severity of the winter; in a mild winter, few bison approached the parkland. Rather than seeking refuge deep in the woods, parkland- and forest-adapted peoples wintered on the margins of the zone of high concentrations of bison, usually the northern edge of the plains. Under this strategy they increased their chances of intercepting wintering herds while minimizing the chance of coming into conflict with plains-adapted groups. Wintering bison were highly valued by parkland- and forest-adapted groups because of the ease of hunting; if bison were not available, solitary animals, such as elk and moose, would be sought.

By camping in or close to areas with higher concentrations of bison, the mobile hunter-gatherer groups had the opportunity to aggregate. By hunting cooperatively and finding mates, social, political and economic ties were made or enforced. An arena was provided for the informal sharing of myths and philosophies as well as formal ceremonial functions where ideology and symbolism were celebrated through dance, music and costumes.

5 Hypothesized Adaptive Strategies

5.1 Plains Adaptive Strategy

Bison-dependent hunter-gatherers consciously and deliberately took measures to increase the probability that they had ready access to these animals throughout the year. This entailed camping in places where the concentration of bison was highest and most stable; during the winter months, this area was the Northern Plains. The exploitation of bison, highly valued for both its food and nonfood resources, continued throughout the winter unless the forager's food and material needs were not being met under this strategy.

Two distinct strategies were followed by the late Precontact plains groups of the northern grasslands. Either they followed the majority of bison between the summer and the winter grazing ranges or they remained in the summer or winter range throughout the year to take advantage of the smaller numbers of sedentary bison. The latter strategy was followed at the Henry Smith site, situated along the Milk River within the probable summer range of the majority of bison. Small populations of sedentary bison herds were expected to remain in such locations (Epp 1988), suitable for exploitation by small groups of hunter-gatherers over the winter. Archaeological evidence indicates that small-scale bison drives were in operation at the site throughout the year, with peaks in the summer and winter months (Ruebelmann 1988). Wilson (1988:222) suggested that seasonally restricted large drive kills were only necessary in situations were bison where seasonally unavailable, either from their regular migration or from the loss of mobility experienced by hunters under harsh or unpredictable environmental conditions; stored meat was required only under these conditions. If bison were available, small-scale drives operated

throughout the winter would supply sufficient food for the group (Wilson 1988:222).

Foragers remaining on the summer range expended less energy than those who followed the large herds north; however, small groups remaining in the winter range would lose the social benefits associated with large aggregations of bands. Unless social activites were scheduled at other times of the year, this strategy could only be employed on a limited basis. The cost of this strategy is that greater risk was incurred by remaining in an area when concentrations of bison are relatively low. The potential hazards are exemplified in the archaeological record of the Lost Terrace site, where Avonlea hunters avoided possible starvation by communally hunting antelope (Davis and Fish 1988). In order to reduce the risk, hunter-gatherers could either move into the winter range where the concentration of bison was higher or store dried provisions for emergency use.

Historic accounts indicate that vast numbers of bison wintered in parts of southern Alberta and southwest Saskatchewan. The northern grasslands produce a high quality of abundant and nutritious forage (Bamforth 1988:56-64), which would attract wintering populations. Forage would be accessible on the wind-swept plains and the large aggregations of the animals would provide mutual protection from the extreme cold and wind (Bamforth 1988:50-52). Communal hunting was a regular occurrence, including large scale operations involving hundreds of people. On the northern plains, it was a low risk, high yield activity. It is less likely that hunter-gatherers wintering in areas where bison were abundant and stable needed to store large amounts of fat-rich dried meat provisions, such as pemmican, in the fall or exploit seasonally abundant fat-rich resources, such as fish. When adults became fat-depleted, pregnant females were hunted for the

foetal bison they were carrying; later, newborns were taken in communal kills. Only the storage of seasonally unavailable carbohydrate-rich foods, such as roots, seeds and berries, for winter consumption was required. Reducing the amount of stored foods also increased the mobility of these plains-adapted people enabling them to match large-scale bison migrations more easily.

The factors involved in selecting a particular settlement strategy are not well known. There may have been environmental or political considerations; alternatively, the decision may simply reflect personal/small group preference. People living on the plains may have had their choice of adopting one strategy over the other. Binford (1980) recognized two different types of hunter-gatherers, foragers and collectors. Foragers move consumers to the goods with frequent residential moves while collectors move the goods to the consumers with generally fewer residential moves (Binford 1980:15). The strategies of the late Precontact hunter-gatherers do not form perfect matches with Binford's definitions, but certain aspects are common.

The strategy of all plains-adapted hunter-gatherers, both those who followed the bison and those who did not, is similar to that of Binford's (1980) foragers. By remaining close to bison throughout the year, the resource base of plains people was generally stable. There is evidence of communal hunting activities directly or indirectly associated with virtually all winter sites located on the plains, although there is a difference in the scale of the operations and distance of residential moves. In the fall, the majority of bison moved from the summer grazing range to the winter range; but small herds remained in the summer range throughout the year (Epp 1988). Likewise, the majority of hunter-

gatherers moved to the winter range allowing small groups of hunter-gatherers to remain in the summer range with sufficient numbers of bison to sustain themselves throughout the winter. The long-distance foragers could operate large-scale communal bison hunts in the winter range while the short-distance foragers operated small-scale hunts in the summer range.

5.2 Parkland and Forest Adaptive Strategies

Unlike plains-adapted people, parkland- and forest-adapted peoples likely spent only a portion of the year, the warmer months, in the vegetation zone to which they are associated. As indicated in the historic record, the proximity of bison attracted both parkland- and forest-dwellers to the grassland-parkland transition zone where camps were formed on the northern edge of the grassland and in sheltered aspen groves along the southern edge of the parkland. The transient and unpredictable nature of bison in the parkland made it necessary for parkland and forest-adapted people to adopt mixed-strategy solutions and a broader subsistence base than that typical of a plains adaptive strategy. When readily available, bison were exploited; when absent, the people turned to other sources of food. When the number of bison declined, rather than moving to a different location other resources, such as fish, would be added to the diet. This strategy most closely resembles Binford's (1980) description of collectors.

Although Smith (1988) and Smith and Walker (1988:86) proposed a similar strategy for Northern Plains groups, it probably reflects the behavior of parkland- and forest-adapted groups wintering in the transition zone. Bison in concentrations high enough to readily facilitate the operation of pounds in winter were probably only found in

the grassland and transition zone. This is consistent with the archaeological record as few pounds or jumps occur deep within the parkland. Groups wintering in the transition zone could exploit bison from early fall to late spring, in a normal winter. This proximity to bison permitted these people to follow, essentially, a plains adaptive strategy during the colder parts of the year.

By camping on the edge of parkland, the potential hazards associated with severe winter storms were reduced, but there was a risk that migrating bison might not reach the more wooded areas. Some bison moved close to and usually into the parkland in winter but their concentrations were lower than on the grassland; the movements of these bison were less predictable as one moved deeper into the parkland. During mild winters bison remained far out on the plains, out of the hunting range of people hesitant, for any reason, to travel far into the grasslands.

While some parkland-adapted people knew how to successfully operate a pound, in the Precontact Period those based in the northern parklands and southern boreal forest-dwellers possessed hunting skills suitable for diffuse resources. Rather than communal hunts, these people were accustomed to taking solitary animals, such as moose and elk. According to Russell (1991:117), after the collapse of the alliance with the Blackfoot confederacy in the late 1700s it was necessary for the Cree to form larger winter camps for self protection. The need of greater food supplies to support large winter camps added pressure for the Cree to adopt the pound as a hunting technique. Immediately prior to this, the Cree had no fear of enemies and winter camps remained small (Russell 1991:117).

Diffuse resources would not pose a problem to parkland- and forest-dwellers, who exploited a wider variety of animals and plant, and formed small winter camps in the area. The faunal assemblage of the Lebret site, located on the Fishing Lakes, contains the remains of bison, moose, elk, small mammals, fish and waterfowl (Smith and Walker 1988). Probably by virtue of the projectile point they used, Smith and Walker (1988:82) assume the former occupants at the Lebret site were plains people "pursuing a non-typical Plains lifestyle;" however, Avonlea sites located deeper in the parkland and occupied in the late winter/early spring also contain evidence of a mixed strategy. The former occupants of the Miniota site appear to have followed a mixed strategy (Landals 1994). A mixed subsistence strategy is typical of Avonlea sites near the forest-edge. According to Joyes (1988:232), the Avonlea component at The Pas site "clearly does not represent an intrusive bison-hunting interval, but an occupation, like others at the site, adapted to a boreal forest environment." Beaver and muskrat each form over 30% of the mammal remains at the site, moose formed 10% while bison represented only 7% of mammal remains. Waterfowl and bird bones were abundant at the site. Meyer *et al.* (1988:39) indicate that the remains of elk, beaver and fish were recovered from the Gravel Pit site (FhNa-61), an Avonlea site near Nipawin. Avonlea points have also been recovered from the Goldsworthy site, a major spring spawning fishery in east-central Saskatchewan (Meyer *et al.* 1988:39). It is quite possible that the Avonlea peoples who wintered in the transition zone, at sites such as Lebret, formed their summer camps in the parkland or southern boreal forest.

A similar shift in subsistence patterns occurs on the southwestern edge of the

plains in Montana. Within the pine parkland south of the confluence of the Yellowstone and Tongue Rivers in Montana, sites contain evidence of mixed fauna utilization and indirect evidence of plant processing (Fraley 1988:133). To the north the change in environment from pine parkland to plains is accompanied by a change in subsistence strategies. Goheen is a mid-late winter site on the northern edge of the pine parklands in east-central Montana (Fraley 1988). The subsistence pattern of the Avonlea occupants, like other Late Precontact Period sites on the glaciated plains north of the Missouri River, "indicates an almost singular emphasis on communal bison procurement" (Fraley 1988:133). The subsistence strategy followed in this zone of transition between the plains and pine parklands in Montana is essentially identical to that observed in the grassland-parkland transition zone in Saskatchewan and Manitoba.

These parkland- and forest-adapted groups followed a true mixed strategy. When bison were not available, other game animals, such as deer, elk and moose, were taken. The diversity in their diets enabled them to utilize seasonally abundant resources, including fish. Stores of dried foods for late winter/early spring use were probably important to parkland- and forest-adapted groups. Groups who wintered deeper in the parkland, those who were based in the northern parkland and forest, had more limited access to bison over the course of the winter. Drowned bison floating down rivers after spring break-up were probably utilized as a food source. John MacDonald of Garth (Morton 1973:xlvii) indicated that many bison drowned in the North Saskatchewan River in the spring:

> It was a Grand Sight to me to see such a Grand River, the innumerable herds of Buffalos & Deer & many grizle Bears on its Banks feeding & crossing in such numbers that we often got our canoes amongst them &

> short hundreds without need. There lay sometimes upwards of a thousand dead on some low points drowned while crossing in Spring on the ice & washed ashore.

Alexander Henry the Younger (1988) documented Native use of drowned bison in the spring while at the Pembina River posts. Terrance H. Gibson (personal communication, 1985) believes that late Precontact Selkirk populations at Bushfield West, near Nipawin also utilized drowned bison in the spring.

5.3 Summary

Over the winter, there were large, stable populations of bison on the northern regions of the plains. Groups wintering in this area were virtually guaranteed a ready supply of bison from late fall until early spring. Fewer bison remained in the summer range so plains-adapted people who chose to winter in this area faced a greater risk of losing their supply of fresh meat. If a shortage of bison was experienced, they exploited other game animals, such as pronghorn. When adult bison became fat-depleted in late winter, pregnant females or cow/calf herds were communally hunted for foetal and newborn bison. Fish were not regularly used by truly plains-adapted people.

Groups based in the parkland and the boreal forest could travel south to the grassland-parkland transition zone where bison were available, except in extremely mild winters. Some of the parkland- and forest-adapted groups were even skilled communal hunters. The numbers and stability of wintering bison declined in more wooded parts of the parkland. By necessity, groups remaining in the more wooded areas over the winter hunted moose, elk and bison, all diffuse resources. Both parkland- and forest-adapted groups maintained a mixed subsistence base using bison, moose, elk, fish and waterfowl.

The different adaptive strategies followed by the groups would be manifested in the archaeological assemblages of the sites they occupied (Table 2). The faunal and artifact assemblages and the composition of pottery residues of those following a plains adaptive strategy would be different from those following parkland or forest adaptive strategies.

5.4 Framework for Testing the Proposed Adaptive Strategies

In order to test the proposed strategies, it is necessary to make assumptions about the behavior of the late Precontact inhabitants of Western Canada and how this behavior may be reflected in the archaeological record. These assumptions are outlined below:

Assumption 1: Pottery was used throughout the winter.

The only direct observation of pottery use outside the Missouri River Villages was made by Matthew Cocking in 1772, at two different Atsina Fall Indian camps about 100 km southwest of modern Saskatoon, in the vicinity of the town of Ruthhilda (Russell 1991:107; Malainey 1991:359). Cocking (1908:108) found the remains of one vessel described as an earthen pan at an abandoned camp site in October 1772. On 5 December 1772, he (1908:111) observed the Atsina Fall Indian prepared their food in pots that were "much in the same form as Newcastle pots, but without feet." It is assumed that the use of pottery for cooking would continue throughout the winter.

Assumption 2: Most taxa utilized at a significant level are either represented or implied, directly or indirectly, in the material residues at a site.

Indications of important taxa should exist even in situations where conditions are less favourable for the preservation of bone, such as parts of the boreal forest. However, the acidic soil conditions which quickly destroy bone are not uniform throughout the

Table 2. Proposed Adaptive Strategies and Predicted Archaeological Evidence

ADAPTIVE STRATEGY	PLAINS	GRASSLAND-PARKLAND TRANSITION ZONE	NORTHERN PARKLAND/ BOREAL FOREST
Seasonal Inferences	virtually all camps located in the grasslands throughout the year; settlement locations mirror general bison movements	virtually all camps located in the parkland and northern grasslands; winter camps located on the fringes of wintering bison concentrations, i.e. grassland-parkland transition zone	winter camps located within the parkland; summer camps located on northern parkland edge or southern boreal forest
Faunal Assemblages	bison dominates; dog, antelope, deer may be present; small mammals, birds or fish rarely occur.	bison common or dominant in fall and winter; moose, elk, deer, bear, fish, waterfowl, beaver, muskrat and other small mammals may be present	moose, elk, fish, waterfowl and small mammals most common; bison present in fall and winter, may dominate spring sites along rivers
Artifact Assemblages	typical of hunting economy -projectile points, scrapers, anvils, knives	typical of hunting economy - projectile points, scrapers, anvils, knives; some evidence of fishing for subsistence- harpoons.	typical of hunting and fishing economy
Pottery Residues	evidence of ungulates, mainly bison, plants and berries; fish rarely, if ever, present	evidence of ungulates, mainly bison, plants and berries and fish	fish, waterfowl, small mammals, plants and berries; possibly some evidence of ungulates

boreal forest. Recent recoveries from burial contexts in the boreal forest have yielded fish and bird remains from the Middle Woodland Period at The Pas site and bird as well as mammals dating back to circa 4,300 BP at the Victoria Day site (E.L. Syms, personal communication 1997). Even under optimal soil conditions, exposure to sedimentary abrasion and trampling causes differential bone preservation. Most fish bone, particularly boiled bone, deteriorated faster than mammal, bird and amphibian bone (Nicholson 1992).

In cases where bone survival was not optimal, other lines of evidence must be considered. Indirect evidence of taxa used at significant levels would exist in the tool assemblage. Evidence for the significant use of a species would exist as chemical traces in residues if foods were prepared in pottery vessels.

Assumption 3: The distribution of certain types of pottery can be used as an indicator of the settlement pattern of its makers.

When a pottery type is restricted in distribution to certain vegetation zones it can be used as an indicator of the settlement pattern of its makers. When a pottery type is widely distributed across the plains, parkland and boreal forest it can not be use as an indicator of settlement pattern.

Assumption 4: The season of site occupation inferred is accurate where several lines of evidence supporting the inference exist.

In order to test the proposed settlement and subsistence strategies, it must be possible to infer the season during which a campsite was occupied. In most cases, information gleaned from the faunal assemblage is used to identify the season of occupation. The existence of several lines of evidence supporting a particular seasonal

designation increases the level of confidence in that designation.

Assumption 5: The analysis of residues from vessels in the study area can provide insights into the types of foods consumed by the users.

It is assumed that the cooking practices of late Precontact peoples in the study area were such that residues absorbed in pottery represent traces of food. The analysis of these residues will then provide an indication of the diet of those who used the vessels. Ethnographic and historical accounts support the validity of this assumption. The importance of soups and stews in the diet of the original inhabitants of the region has been noted by several observers (Wissler 1912; Kroeber 1908; Flannery 1953; Mandelbaum 1979); presumably at least some of these were prepared in clay pots. As late as 1772, Atsina Fall Indians were observed preparing a meal, consisting of a mixture of berries, water and fat, in earthenware vessels (Cocking 1908:111; Russell 1991:106). The potential and limitations of pottery residue analysis are discussed in Chapter 7.

Hypothesis 1: People employing a plains adaptive strategy followed a subsistence and settlement pattern which optimized their access to a supply of red meat, especially bison, throughout the year. Fish was generally avoided even when the resource was readily available when they spawned in the early spring.

The cooking residues from the pots of those following a plains-adaptive strategy should reflect a red meat/berry/root diet throughout the year. The red meat component of diet will consist mainly of bison, although other species such as dog, deer and pronghorn antelope may also appear. Further evidence for this diet pattern should exist in the artifact and faunal assemblages as well as human bone isotope analyses. Evidence of fish use

should be absent or extremely rare at these sites, even in sites on lakes and rivers where fish were readily exploitable.

Hypothesis 2: People following a parkland or forest adaptive strategy exploited a diverse resource base including a variety of large ungulates, waterfowl, fish and small mammals. In the winter, they travelled to the northern edge of the plains in order to access transient herds of wintering bison. The supply of bison was less reliable so it was necessary for these people to exploit a more diverse resource base than plains-adapted peoples.

This diversity in the diet of nomadic parkland- and forest-dwelling people should be evident in faunal assemblages, tool kits and in vessel residues. Evidence of fish residues and diet diversity should be geographically limited to the transition zone, parkland and southern forest.

5.5 Requirements for Model Testing and Site Descriptions

1) Materials from late winter and early spring occupations/sites are needed from the plains, parkland and southern boreal forest.

2) Sites must contain pottery with absorbed residues.

3) Basic descriptions of the tool and faunal assemblage must exist.

Sites excavated by professional archaeologists, with analyzed faunal assemblages complete with fine-screened samples are preferable. In order to test the model, residues absorbed in the walls of cooking pots should provide an indication of its former contents, in particular, the presence or absence of fish and the diversity of vessel contents as a measure of diet breadth. The artifact assemblage should reflect the relative diversity of food gathering

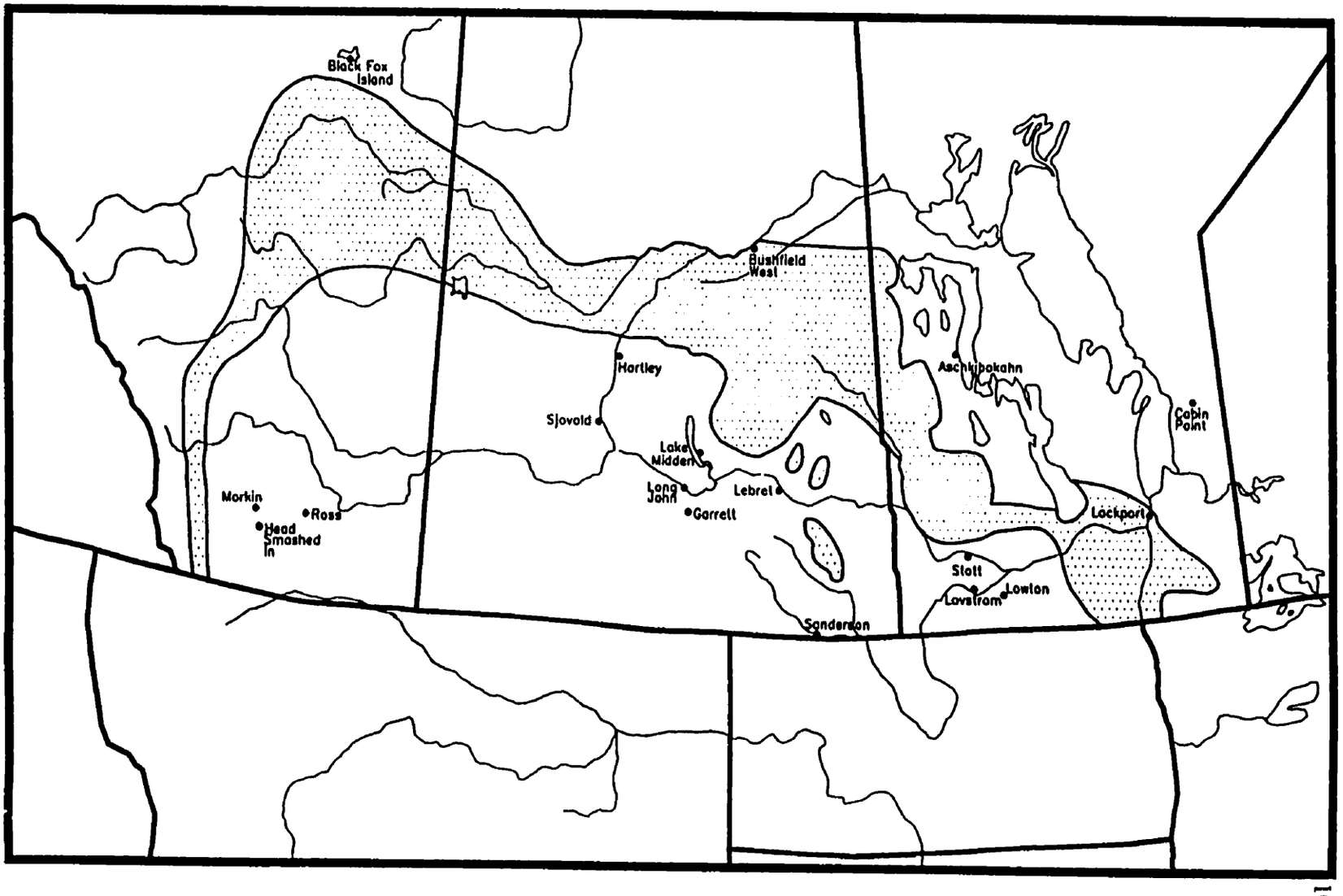
activities. Calculations based on the minimum number of individuals (MNI) of each taxa of food animals represented at the site, as reported in extant faunal analyses, should provide a gross estimate of the dietary importance of a particular species (Lyman 1982:362).

Site selection is restricted to the pottery-bearing cultures of the Late Precontact Period. Material from the plains, transition zone, parkland and southern boreal forest sites has been examined in the course of this study (Table 3). The locations of these sites are shown in Figure 6. Detailed descriptions of these sites can be found in Appendix A; descriptions of each sherd analyzed are provided in Appendix B. A general overview of the Late Precontact Period pottery of Western Canada, including the range of vessel forms observed, can be found in Malainey (1995b).

Table 3. Sources of Material Used in the Testing of the Proposed Settlement and Subsistence Strategies

Zone	Site Name	Borden No.	Location	Pottery	Samples
Prairie	Morkin	DlPk-2	southern Alberta	Late Var. Saskatchewan Basin	14
	Ross	DlPd-3	southern Alberta	Late Var. Saskatchewan Basin	12
	Head Smashed In	DkPj-1	southern Alberta	Late Var. Saskatchewan Basin	4
	Long John	EeNj-1	southern Saskatchewan	Mortlach	14
	Garratt	EcNj-7	southern Saskatchewan	Late Var. Sask. Basin and Avonlea	13
	Sjovold	EiNs-4	south-central Saskatchewan	Wascana and Avonlea	4
	Sanderson	DhMs-12	southeast Saskatchewan	Mortlach	16
Transition	Hartley	FaNp-19	central Saskatchewan	Avonlea/Old Women's	10
	Lake Midden	EfNg-1	south-central Saskatchewan	Wascana	16
	Lebret	EeMw-26	southeast Saskatchewan	Avonlea	12
	Lowton	DiLv-3	southwest Manitoba	Vicker's Focus	14
	Lovstrom	DjLx-1	southwest Manitoba	Vicker's Focus	3
	Stott	DlMa-1	southwest Manitoba	Blackduck	17
Parkland	Bushfield West	FhNa-10	east-central Saskatchewan	Pehonan Selkirk	19
	Lockport West	EaLf-1	southern Manitoba	Red River	8
Forest	Aschkibokahn	FbMb-1	west-central Manitoba	Duck Bay	18
	Cabin Point	EgKx-1	southeast Manitoba	Selkirk and Blackduck	17
	Black Fox Island	GfPa-32	north-central Alberta	Selkirk (?)	1

Figure 6. Locations of sites used to test hypotheses.



Chapter 6 - Methodology: Vessel Residue Analysis, Lipids and Gas Chromatography

The identification of vessel contents can heighten our understanding of the people who used the pottery by providing information on function, diet, material science and trade. The potential for valuable information to be acquired through the study of archaeological vessel residues depends upon several factors including 1) the nature and selection of the residue, 2) the degree and nature of sample processing prior to analysis, 3) the analytical technique chosen and its implementation and 4) interpretation of the data. Almost any analytical technique will provide some information about the residue but some types of analyses are more appropriate than others under certain conditions.

Another, perhaps the most important consideration, is the research question being addressed. If one wishes to test for the presence of a specific compound, then infrared spectroscopy, high-pressure liquid chromatography, or gas chromatography with mass spectroscopy (GC/MS) may be the best choices. When the nature of vessel contents is not known, broader characterizations of the residue are necessary. For the purposes of this project, where a large number of vessel residues of unknown composition were examined, high performance gas chromatography (GC) was employed.

In this chapter, examples of the characterization of archaeological vessel residues using GC is presented. A general description of fatty acids and the enzymic and oxidative processes which alter the fatty acid composition of a substance are given. A general description of GC analysis is offered, as well. Finally, the experimental procedures followed during the course of this study are presented, including the establishment and

analysis of a modern reference collection, the preparation and decomposition of experimental cooking residues and archaeological sherd selection and processing.

6.1 Vessel Residue Lipid Analysis with Gas Chromatography

Over the past 30 years, lipids, specifically fatty acids, sterols and waxes, recovered from the surface or absorbed into the walls, have been used to characterize the former contents of archaeological vessels. Rottländer (1990:37-38) suggests that lipid analysis is most suitable for the study of vessel residues because lipids are present in virtually all human food, they have a relatively high stability with increased temperature (up to 400°C) and their decomposition from cooking temperatures is minimal. By contrast, carbohydrates undergo hydrolysis to form water-soluble compounds that can be washed away. Carbohydrates decompose at temperatures from 200-220°C; proteins decompose from 150- 200°C in air (Rottländer 1990:38).

For many years, researchers have concentrated on the fatty acid component of the residue samples. Certain fatty acids are present at very high levels in some foods and are rare in others. Furthermore, the ratio between fatty acids may be distinctive for different food groups (Patrick *et al.* 1985; Deal 1990). Skibo (1992:83) favours the archaeological study of fatty acids because 1) they occur in different combinations and in different proportions in every plant and animal species, 2) they survive normal cooking temperatures, and 3) fatty acids can survive (although not without some change) long periods in the depositional environment. In general, the fatty acid composition of food varies with type.

Evershed *et al.* (1992) and Heron and Evershed (1993) regard GC and GC/MS to

be the tools of choice for the analysis of lipids from archaeological vessel residues, although other analytical techniques can and have been utilized. Various forms of GC have been used to provide a characterization of the overall lipid composition of a vessel residue. Condamin *et al.* (1976), Shackley (1982) and Marchbanks (1989) used GC; Patrick *et al.* (1985) and Hill and Evans (1988) used gas liquid chromatography (GLC). GC/MS has been used extensively to analyze archaeological samples, including carbonized pot residues (Deal and Silk 1988; Deal 1990; Heron and Pollard 1988; Heron 1989; Evershed *et al.* 1990; Gerhardt *et al.* 1990; Evershed *et al.* 1991; Heron *et al.* 1991; Skibo 1992; Charters *et al.* 1995).

6.2 Gas Chromatography for Vessel Residue Analysis

Condamin *et al.* (1976) first used GC to identify the contents of amphorae thought to have once held oil, but lacking visible residues. Samples of olive oil, amphora likely to have contained oil, (unused) amphorae broken during manufacture and a gallo-roman lamp were analyzed. Fatty acids characteristic of olive oil were detected in the walls of used amphorae and the lamp, but not the unused amphorae.

Patrick *et al.* (1985) used GLC to determine that the brown flaky residue found on the inside of potsherds from South Africa likely originated from either Grey Atlantic or Cape Fur seals. This identification was supported by the remains of seal recovered from the site. The researchers (1985) concluded the seal meat was likely prepared by boiling.

Hill and Evans (1988) used GLC to recognize the presence of seed fats in one residue and fish or fish products in another sample from the Solomon Islands. Marchbanks (1989) used GC, GC/MS and thin-layer chromatography (TLC) to study a

large assemblage of vessels from a Caddoan site in central east Texas. Marchbanks (1989:81) demonstrated there was a relationship between vessel form and the foodstuffs which were cooked or stored in them.

Deal and Silk (1988) used GC and GC/MS to study vessel residues from the Chiputneticook-St. Croix drainage system on the Maine-New Brunswick border. On the basis of ethnographic evidence, Deal and Silk (1988:114) considered the elevated levels of saturated fats related to the production or storage of edible animal fats, such as moose. Two other samples contained high levels of both stearic acid (C18:0), and behenic acid (C22:0) which is generally found in plant oils, suggesting both animal and plant materials were processed in the pot (Deal and Silk 1988:114-116).

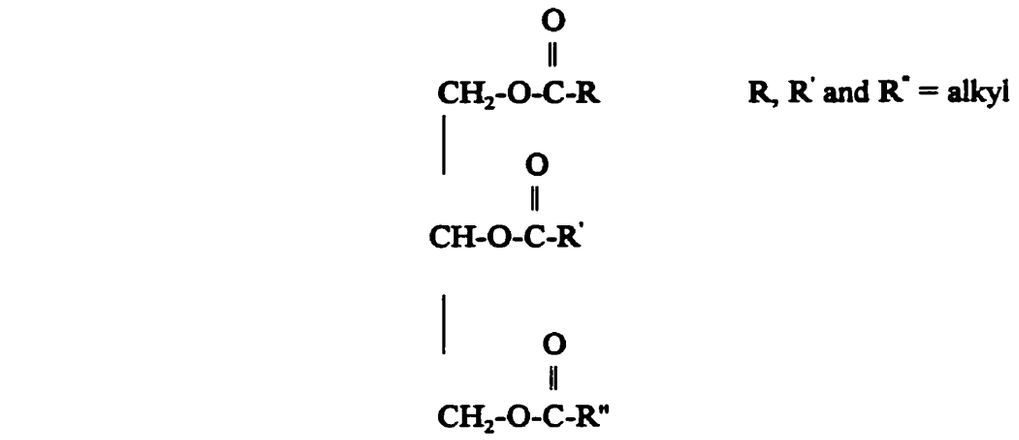
Skibo (1992) extracted fatty acids from modern Kalinga pots to determine if a correlation existed between what was cooked in the pots and the remnant fatty acids. Skibo (1992:96) concluded a strong link between fatty acids in the residue and the material of origin existed when only one food item was cooked in the pot. In pots used to cook a variety of plants and animals, fatty acid ratios were less useful; individual species could be identified only if "signature" fatty acids were present.

While the initial fatty acid composition of different types of food is fairly distinctive, fatty acids decompose under thermal, oxidative and microbial processes. Because the composition is described as relative percentages, a change in the amount of one fatty acid changes the level of all others. When attempting to identify an archaeological vessel residue one must consider both the initial fatty acid composition of foods as well as the effects of cooking and decomposition over time.

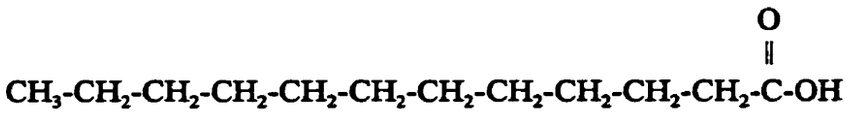
6.3 Fatty Acids

Lipids are substances which are soluble in organic solvents but have very low solubilities in water (Nawar 1985; Solomons 1980; Christie 1989). There are several classes of lipids but archaeological interest has focused only on fatty acids, sterols and waxes. The focus of this research is fatty acids. In nature, they occur as triacylglycerols, which consists of three different fatty acids ester-linked to a glycerol molecule (Figure 7a), and represent about 99% of all lipids in plant and animal material. Fatty acids which have been hydrolyzed from the triacylglycerol are referred to as free fatty acids.

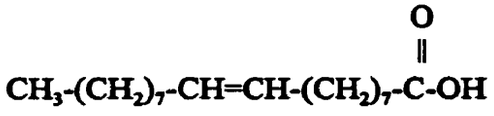
There are saturated and unsaturated fatty acids. In saturated fatty acids, each carbon in the chain is connected to its neighbouring carbons by single bonds, which makes them relatively stable (Figure 7b). The most abundant saturated fatty acids have chain-lengths of either 14, 16 or 18 carbons. Mammal fats primarily consist of saturated fatty acids and are solids at room temperature. Unsaturated fatty acids contain at least one carbon-carbon double bond, or point of unsaturation (Figure 7c). The point of unsaturation is susceptible to addition reactions because the conversion of one double bond into two single bonds is "energetically favorable" (Solomons 1980:238-239). Unsaturated fatty acids are the primary constituents of plant and fish oils and tend to be in liquid-state at room temperature. They have chain-lengths of a minimum of 12 carbons; most common unsaturated fatty acids contain at least 18 carbon atoms. Fatty acids with multiple double bonds, polyunsaturated fatty acids, are very unstable and oxidize readily.



a) triacylglycerol



b) a saturated fatty acid



c) an unsaturated fatty acid

Figure 7. Illustrations of a) a triacylglycerol, b) a saturated fatty acid and c) an unsaturated fatty acid.

6.4 Enzymic Degradation of Fatty Acids

Although saturated fatty acids do not contain carbon-carbon double bonds, they are subject to enzymic degradation under certain conditions. One mechanism, β-oxidation, is essential for the conversion of stored body fat into energy. Fatty acids are built up by successive condensations of 2-carbon units; as a result, most have even numbers of carbon atoms in the chain (Gurr and James 1980:27). Conversely, β-oxidation is the process by which stored fatty acids are broken down 2-carbon units at a time to yield energy. The 2-carbon fragment is converted into an energy-rich molecule, known as adenosine triphosphate (ATP) (Gurr and James 1980:27). This process occurs exclusively in cell mitochondria (Lehninger 1970:419).

A type of enzymic degradation frequently cited by archaeologists as a factor in the identification of archaeological residues is adipocere formation, as described by den Dooren de Jong (1961). Adipocere is a product of the incomplete decomposition of human and animal remains which consists largely of palmitic (C16:0) acid (den Dooren de Jong 1961:337). It is known to form in human remains buried in oxygen-depleted zones, such as the third and fourth coffins from the top in stratified cemeteries. Den Dooren de Jong (1961) conducted a series of experiments into adipocere formation examining the bacterial influences on fats under anaerobic conditions. He (1961:341) found the soil bacteria altered the composition of olive oil dramatically. The levels of oleic (C18:1) acid were reduced from 70-83% to 18.5%; palmitic acid levels increased to 53.5% and hydroxystearic acid levels to 19%. Den Dooren de Jong (1961:342-343) suggested the palmitic (C16:0) and acetic (C2:0) acid was formed from oleic (18:1) acid through the "β-

like" oxidation coupled with a hydrogenation mechanism:

$$CH_3(CH_2)_7CH = CH(CH_2)_5CH_2CH_2COOH$$
oleic acid ⇓
$$CH_3(CH_2)_7CH = CH(CH_2)_5CH{=}CHCOOH + 2\,H$$
$+ H_2O$ ⇓
$$CH_3(CH_2)_7CH = CH(CH_2)_5CHOHCH_2COOH$$
⇓
$$CH_3(CH_2)_7CH = CH(CH_2)_5COCH_2COOH + 2\,H$$
$+ H_2O$ ⇓
$$CH_3(CH_2)_7CH = CH(CH_2)_5COOH + CH_3COOH$$
palmitoleic acid ⇓ + 2 H acetic acid
$$CH_3(CH_2)_7CH - CH_2(CH_2)_5COOH$$
palmitic acid

Similarly, Morgan *et al.* (1973:9-10) were able to convert fresh butter to an adipocere-like substance under water-logged, anaerobic conditions. Nutrients and soil were added so that the butter was under conditions simulating burial in a peat bog. The pathway proposed for the formation of adipocere has not been confirmed but during the transformation of fats to adipocere "the unsaturated fatty acids tend to disappear and are replaced by saturated fatty acids of two fewer carbon atoms" (Morgan *et al.* 1983:359). These studies provided the basis for identifying partly degraded fatty residue found in a Thule midden at the Washout site (NjVi-2) on Herschel Island (Morgan *et al.* 1983). Silt-capping, permafrost and waterlogging produced anaerobic conditions so the organic material had an excellent level of preservation. The researcher used cumulative percentage fatty acid composition plots to show that the material in the midden more closely resembled seal fat. This identification was supported by the faunal remains recovered, more than 90% of which was seal.

Some archaeologists consider that the decomposition mechanism proposed for

adipocere formation is a factor in the preservation of fatty acids in archaeological pot residues (Morton 1989; Deal 1990; Skibo 1992). They view this as the primary decomposition mechanism for mono-unsaturated fatty acids, without consideration of the specific environmental and enzymic requirements. Deal (1990:7-8) regards adipocere formation as an important factor in pot residue analysis because it may result in misidentifications. He suggests palmitoleic acid (C16:1), characteristic of cold blooded animals, will be replaced by myristic acid (C14:0), found in milk and palm seed fats and in the head oil of the sperm whale. Similarly, high levels of stearic acid (C18:0) suggest the fat was derived from a ruminant or quasi-ruminant, but Deal (1990:8) cautions that it may also result from the decomposition of gadoleic acid (C20:1), found in marine mammals and fish as well as freshwater fish. Skibo (1992:98-98) regards adipocere formation to be a product of hydrolysis, without reference to the enzyme-catalyzed degradation similar to β-oxidation.

Adipocere forms by a microbial or enzymic degradation process which only occurs under anaerobic conditions. In order for this mechanism to occur, the oxidation of the saturated end of the fatty acid must occur prior to hydrogenation of the double bond in oleic acid. Because of the specific environmental requisites for this fat conversion, adipocere formation is not necessarily of consequence to vessel residue analysis. As discussed in the following section, the oxidation of fatty acids usually results in the formation of hydroperoxides and other volatile end products, not other fatty acids.

6.5 Oxidative Degradation of Fatty Acids

Unsaturated fatty acids, in particular, polyunsaturated fatty acids, those with more

than one double bond, are susceptible to peroxidation. The most common type of peroxidation is autoxidation defined as "oxidation by molecular oxygen under usual conditions of temperature and pressure" (Mead *et al.* 1986:83). Monounsaturated, and even saturated fatty acids, can undergo autoxidation, but at a rate that is much lower than for polyunsaturates. Polyunsaturated fatty acids oxidize very rapidly if not protected from air because the lipid catalyzes its own oxidation (Gurr and James 1980:80). They undergo peroxidation which leads to tissue degradation and food spoilage. Frankel (1991:496) regards the oxidation of polyunsaturated fatty acids as one of the most fundamental reactions of lipid chemistry.

The most stable configuration for polyunsaturated fatty acids is the conjugated form where double bonds and single bonds alternate along the chain as follows:

-C=C-C=C-

(Solomons 1980:393 and 396). When double bonds are isolated from each other by one or more saturated carbons, stability decreases and oxidation is possible.

The process of free radical autoxidation of lipids is described by Frankel (1991). In the presence of initiators, such as heat, metals, irradiation or light, one of the hydrogen atoms on a saturated carbon between the isolated double bonds is attacked. The hydrogen atom is stripped away forming a carbon-centred alkyl radical. The loss of the hydrogen destabilizes the adjacent double bonds, which shift in order to compensate for the missing atom. Oxygen can then add at a carbon which is β to, i.e. two carbons away from, the radical and form peroxyl radicals.

Common oxidation products are monohydroperoxides containing a set of conjugated double bonds. If isolated double bonds remain in the mono-hydroperoxides, they are susceptible to further oxidation. When the peroxyl group forms between double bonds, the peroxyl radical may undergo cyclization and further oxidation, resulting in the formation of five-membered hydroperoxy epidioxides. Mono-hydroperoxides and hydroperoxy epidioxides are unstable and decompose readily. Carbon-carbon splitting results in a variety of end products, many of which are highly volatile and dissipate quickly. If the hydroperoxides form peroxide-linked dimers then undergo thermal decomposition, a different set of end products results (Frankel 1991:503-504).

Both free fatty acids and triacylglycerols are subject to these decomposition pathways. Polyunsaturated fatty acids esterified to glycerol may experience sequential autoxidation to form mono-, bis- and finally tris-hydroperoxides. These hydroperoxides may form cyclic hydroperoxy epidioxides and/or dimers which are subject to further decomposition, resulting in a variety of often volatile end products. The assortment of resulting compounds combined with the loss of volatile ones makes it virtually impossible to trace the identity of the original lipid through its decomposition products.

6.6 Thermal Decomposition of Lipids

As archaeological cooking pots have been exposed to high temperatures, the

thermal decomposition of lipids must be considered. Nawar (1985:205-210) reports that both saturated and unsaturated fatty acids undergo chemical decomposition when exposed to heat in the presence of oxygen. In general, saturated fatty acids must be exposed to temperatures in excess of 150°C before decomposition occurs. Thermal oxidation leads to the formation of mono-hydroperoxides with the oxidation occurring preferentially at the α, β and γ carbons. These products are themselves susceptible to thermal oxidative reactions. The major components of triacylglycerol thermal decomposition are its saturated fatty acids. The extent of thermal decomposition is elevated under oxidative conditions.

When thermal decomposition of unsaturated fatty acids occurs in the absence of oxygen, the formation of dimers is the predominant reaction. At elevated temperatures in the presence of oxygen, unsaturated fatty acids decompose very rapidly. The resulting decomposition products are essentially those expected with autoxidation at room temperature, however, the rate of decomposition is much faster.

Several archaeologists have attempted to recreate archaeological residues to better understand alterations in fatty acid composition associated with cooking and decomposition over time. In order to identify an archaeological specimen of possible seal origin, Patrick *et al.* (1985) prepared a residue by boiling seal tissue, placed it in a 55°C oven for 72 days then heated it another 17 days in a 120°C oven. The researchers used the ratio of oleic to vaccenic acid, which did not alter with decomposition, to identify the vessel residue as boiled seal.

Marchbanks (1989) reported two on-going experiments to 1) study the alteration

of fatty acids over time and 2) determine the effect of food processing technologies. The first experiment involved the study of low-fired ceramic blocks soaked in cooked sweet corn then placed in a burial environment for 1 year, 5 years and 10 years. Other sherds were heated in an oven at 100°C for 5 months and 10 months to increase oxidation rates. In the second experiment, uncooked deer flesh was compared to cooked meat, grease and broth produced by boiling deer in water for four hours. Marchbanks (1989:102) found the "fingerprints" of each substance were distinct in terms of their fatty acid pattern and percent concentration. The broth and grease were similar, but significantly different from the fatty acid composition of both the raw and cooked deer meat. Another sample of deer flesh was placed in an oven in an attempt to simulate long term decomposition processes. No results from these experiments were available.

Evershed *et al.* (1992:195) conducted an experiment involving the slow hydrolysis of beef fat but no details were presented. The chemical composition of the experimental end product was similar to a residue sample from a Bronze Age pot. This, and the results of sterol analysis, strongly suggested the archaeological pot was used in the processing of fatty foodstuffs, probably animal tissue. Evershed and his co-workers (1992:206) reported that laboratory simulations of the decay of other foodstuffs to obtain reference material were in progress. As well, they (1992:199, 206) were performing cooking experiments using unglazed pottery vessels to acquire information on sterol autoxidation in plant and animal foodstuffs and the effects of post-firing vessel treatments on residues.

6.7 Lipid Analysis Using Gas Chromatography

Chromatography is used to separate components in a sample by distributing them

between two phases, one that is stationary and one that moves (Braithwaite and Smith 1985:2). In GC analysis, the stationary phase is a film coated on the inside of the column and the mobile phase is gas. Differences in the physical and chemical properties of the individual sample components determine their relative affinity for the stationary phase; consequently, they migrate through the system at different rates and separate.

When fatty acid methyl esters are examined with GC, the chemical and physical properties used to separate them include volatility, chain-length, the number and position of double bonds, functional groups and reactions to the material coated on the interior of the column. The order of emergence is determined by the nature of the stationary phase. In columns coated with saturated paraffin hydrocarbons or silicone grease, for example, the separation is based mainly on molecular weight (Gurr and James 1980:83). Unsaturated fatty acids emerge from the column earlier than the corresponding saturated acids. Branched chain acids emerge before saturated straight chain acids with the same number of carbons. In the more commonly used columns coated with polyesters, the order of emergence is based on the number of double bonds as well as the molecular weight. Saturated fatty acids emerge first, followed by those with one double bond, then those with two double bonds emerge and so on (Gurr and James 1980:83).

Injection

The three basic steps in GC analysis are sample injection, component separation and detection. First, a sample in solution is injected into the column. It is essential that the volume of sample injected, the point of introduction and the initial temperature be reproducible (Christie 1989); this procedure is often automated. If column conditions are

constant, the same fatty acids in different samples pass through the column at the same rate. This enables the identification of fatty acids in a sample through comparisons with standards with known compositions.

Component Separation

Commonly a long wall-coated open tubular (WCOT), or capillary, column made of fused silica is used for GC analysis. The column is coated internally with the stationary phase having physical properties (degree of polarity) desired by the analyst. As the temperature increases, volatile components in the sample evaporate and are carried along the column by the mobile phase, usually hydrogen or helium gas. Components with a low affinity to the stationary phase tend to remain in the moving stream of gas, passing through the column very quickly. Those with a high affinity partly dissolve in the stationary phase and require more time to pass through the column. Therefore, different components pass through the column at different rates and separate.

Detection

When a separated component emerges from the column, it passes by a detector which records the time lapsed since injection, known as the retention time, and variations in the composition of the column effluent due to the presence of separated components. When the mobile phase alone is passing through, a zero signal is registered.

The most common method of detection is flame ionization because it has high sensitivity to virtually all organic compounds and little or no response to water, carbon dioxide and other impurities (Braithwaite and Smith 1985:165-166). The only disadvantage is that a small degree of loss through heat-induced decomposition (pyrolysis)

may occur.

Upon emerging from the column a separated component is mixed with hydrogen and air then passes by a flame where it undergoes combustion. The resulting thermal fragmentation and free radical reactions causes ionization to occur:

$$CH\cdot + O\cdot \rightarrow CHO^{+} + e^{-}$$

As the ions pass a collector electrode, a current is observed, the strength of which is related to the concentration of charged species present. The signal recorded is proportional to either the concentration or the mass of the separated component (Braithwaite and Smith 1985:165-166).

When using flame ionization detectors, identification of sample constituents is based on retention times and comparisons made against known standards run under identical conditions. Retention times and degree of separation observed depend upon the precise column conditions and vary with the temperature, age of the column and degree of contamination. External references used in the comparisons are run on the same columns under identical conditions, before, during and after a series of samples (Christie 1989:90). Resolution increases if narrower bore fused silica columns are used. The separation and certainty of identification is enhanced with GC/MS because the molecular weight of the compounds or fragments are determined.

6.8 Analysis of Vessel Residues

Researches have used different approaches to determine vessel contents from residues, they have either analyzed carbonized residues adhering to the surface of the vessel or residues absorbed into the vessel fabric. The utility of carbonized residues for

the analysis of vessel contents has been questioned by some researchers. Rottländer (1990:39) suggests that absorbed residues are better protected than carbonized surface deposits and less likely to have been subjected to decomposition and contamination. Hill and Evans (1989:420) argue that charred encrustations are likely "sterilized" by the high temperature that produced them. The charred material, however, serves as a protective layer which shield the organic material absorbed in the pores from decomposing agents.

Recent studies by Oudemans and Boon (1991), using Curie-point pyrolysis-gas chromatography, and Sherriff *et al.* (1995), using NMR demonstrate that, in addition to lipids, evidence of polysaccharides and amino acids are preserved in carbonized residues. Although valuable information can be gained through the study of carbonized residues, in the case of NMR analysis, 1 g is required. In general, a large section of vessel must be scraped to provide sufficient residue for analysis. Few Precontact pottery vessels in Western Canada have been reconstructed and even less have accumulations of residue available for analysis. In this study, only absorbed resides are examined.

6.9 Sources of Contamination

The effects of two potential sources of vessel residue contamination have been examined: 1) the soil in the burial environment and 2) archaeological processing. Condamin *et al.* (1976) compared the fatty acids from the interior and exterior surfaces of Roman amphorae to adjacent soil. The concentration of fatty acid from the vessel interior was eight times higher than those from the exterior; the soil adhering to the vessel wall had a very low concentration of fatty acids (Condamin *et al.* 1976:199). The researchers concluded that the fatty acids in the vessel fabric originated from its former contents and

the level of contamination of the vessel with fatty acids from the surroundings was negligible.

Heron *et al.* (1991) compared organic constituents of the buried soil to those representing former vessel contents. They found that soil samples, including those directly adhering to potsherds, contained a complex mixture of lipids including long-chain both odd- and even-carbon number saturated fatty acids (C16:0-C33:0), mainly pentacosanoic acid (C25:0), odd-carbon number n-alkanes (C21:0-C33:0) and wax esters (C42-C56) (Heron *et al.* 1991:646). Numerous other compounds were also present in very small amounts. By contrast, the sherd extracts were composed of acyl lipids, such as intact triacylglycerides and free fatty acids (Heron *et al.* 1991:648). This clearly demonstrated that negligible migration of soil lipids occurs during burial (Heron *et al.* 1991:655). The absence of contamination was attributed to the hydrophobic nature of the lipid molecules.

These results were also supported by Oudemans and Boon (1991:223), who found that the total pyrolysis product profile of the peat adhering to sherds was very different from the residue samples. Similarly, Deal and Silk (1988:113) tested the soil associated with two potsherd samples and found only traces of fatty acids. On the basis of this evidence they ruled out soils as possible sources of contamination but they (1988:112-113) found evidence of phthalates, industrial plasticizer, in their replica bricks. The contaminants were believed to have been absorbed from the plastic sheeting used to cover the bricks during drying and transportation. Similar contaminants were detected in the samples analyzed by Oudemans and Boon (1991:223), who used sherds which had been kept in plastic bags for over one year prior to their analysis.

Oudemans and Boon (1991:224) note that contamination may exist from archaeological processing including washing, dust accumulation, absorption of chemicals from the paper on which washed artifacts dry, and fat from archaeologist's hands. Evershed (1993) suggested that contamination by the handling of archaeologists is manifested by the presence of non-degraded squalene and cholesterol, the major lipid components of finger oils.

In order to extract absorbed residues, it has been general practise to crush the entire sherd intact, but scraped free of adhering soil. An alternative sherd sampling method proposed by Marchbanks (1989:116), involves removing the upper 1 mm of the pottery surface so that oxidized fatty acids are not included in the sample and contaminants, such as plasticizers, related to archaeological processing are also avoided.

Similarly, researchers at the University of Liverpool recently began removing the surface of the sherd with a drill to eliminate traces of possible contamination from the external environment (Charters *et al.* 1995:213). This methodology was adopted for the study of the distribution of lipids on 62 reconstructed vessels from sites in the United Kingdom. They demonstrated that lipids accumulate in particular parts of the vessel as a result of different uses. The lipid content was consistently low in sherds taken from the base of cooking vessels. Charters *et al.* (1995) suggest the heating required for cooking/manufacturing may cause the thermal degradation of any lipids, proteins and carbohydrates absorbed in the lower parts of the vessel. These variations are especially important since it has been traditional to take base sherd samples for analysis.

6.10 Extraction Procedures

Before the lipids can be analyzed, they must first be separated from other substances in a sample. Effective lipid extractions can be made with a combination of two organic solvents, chloroform and methanol in a 2:1 ratio by volume (Christie 1989:28). This combination will dissolve lipids readily and overcome the forces, such as weak hydrophobic or Van der Waals forces, hydrogen bonds or ionic bonds, which link them to other cellular components. In order to increase the efficiency of the extraction, the sample is agitated by homogenization or ultrasonication for several minutes. The solution containing the dissolved lipids is separated from the solids by filtration.

Usually other impurities are removed by washing the lipid-solvent solution with distilled water. When a volume of water, equal to the amount of methanol, is added, the mixture partitions into two layers. The upper one contains mainly water, methanol and the non-lipid contaminants while the lower one is composed of chloroform, a small amount of methanol, a trace of water, and virtually all of the lipids (Christie 1989:29). Once the solvents are removed by evaporation, the remainder represents the total lipid extract containing fatty acids, sterols, waxes and other forms of lipid. Some or all of these lipids can then be subjected to further analysis, such as gas chromatography.

Many compounds can not be readily analyzed by GC because they are not volatile, their separation is not discrete or they are too strongly attracted to the stationary phase. Converting the samples into their methyl ester derivatives make them analyzable by 1) increasing the volatility of the sample, 2) reducing thermal degradation of the sample by increasing thermal stability and, 3) improving separation and reducing tailing (Braithwaite

and Smith 1985:148).

Experimental techniques designed to extract lipids from vessel residues are fairly standardized. Usually, the crushed residue or sherd fabric is washed with a non-polar solvent(s), usually methanol or a mixture of chloroform and methanol, in a Soxhlet apparatus. The lipids are saponified with a strong base, such as NaOH, and converted to methyl esters (Condamin *et al.* 1976; Patrick *et al.* 1985; Hill and Evans 1988; Deal and Silk 1988; Heron 1989; Deal 1990). Saponification transforms fats (triacylglycerols) into simple glycerol, free fatty acids and their salts (Solomons 1980). The free fatty acids are then converted into their methyl ester derivatives which are more volatile, hence, more readily detectable with GC analysis. A variation of this technique, developed by Marchbanks (1989), involves the isolation of fatty acids from other lipids using thin-layer chromatography prior to GC analysis.

Recently, Evershed *et al.* (1990) presented a technique involving a total lipid extraction from powdered sherds with non-polar solvents by ultrasonication and centrifugation. A potsherd, weighing 3 g, is ground into a fine powder with a mortar and pestle then a small amount (10 or 50 μm) of heptadecane is added as an internal standard. Lipids are extracted by adding 10 ml of a chloroform and methanol mixture in a 2:1 ratio and subjecting the sample ultrasonication for 15 minutes. The sample is centrifuged to separate the solvent solution containing the lipids from the solids. The liquid is decanted and the solvent is partially removed by rotary evaporation to reduce the volume. Any remaining solvent is eliminated by placing the sample under a stream of nitrogen, leaving the lipid extract and impurities. Esters and ethers of the total lipid extract are prepared

and analyzed without pre-fractionation. As the sample has not been "cleaned up", a retention gap is used to collect impurities and replaced when any loss of chromatographic performance is observed.

Evershed *et al.* (1990) prefer this technique because the original integrity is preserved, with the exception of the production of trimethylsilyl (TMS) esters and ethers, and time-consuming, "wet" chemistry is eliminated. TMS-esters provide more structural information than methyl esters when analyzing a sample with both GC and GC/MS (Christie 1989:162). They are useful in establishing the locations of double bonds through differences in the intensities of the fragment ion. TMS derivatives may decompose on the stainless steel of an injector port at temperatures greater than 210°C (Braithwaite and Smith 1985:148); Evershed *et al.* (1990:1340) eliminate this problem by injecting the sample at a low temperature. Christie (1989:195) regards low starting temperatures to be a drawback because the analysis time is lengthened and there is additional opportunity for thermal decomposition.

6.11 Summary

Fatty analysis by gas chromatography is useful for establishing the origins of archaeological pot residues; although, both saturated and unsaturated fatty acids extracted from archaeological vessel residues may have undergone substantial changes as a result of autoxidation, thermal and, possibly, enzymic degradation. The relative percentages of fatty acids change through time since fatty acids, especially unsaturated fatty acids, are susceptible to decomposition. It has been suggested the formation of adipocere may affect the composition of archaeological pot residues. This process, however, occurs only under

anaerobic conditions in the presence of particular enzymes and it is not likely to affect archaeological pot residues. Changes in the fatty acid composition are more likely the result of oxidative decomposition and thermal degradation. The effects of these changes can be examined by conducting cooking and decomposition experiments.

Gas chromatography is a method which utilizes the unique chemical and physical properties of the different fatty acid methyl esters to separate the components in a sample. When run under identical chromatographic conditions, the same fatty acids in different samples will emerge from the column at the same time, that is, they will have the same retention times. As a result, the fatty acids in samples under analysis can be identified by comparing its peaks with those in chromatograms from standards of known composition.

When archaeological vessel residues are examined, possible contaminants introduced from the burial environment or subsequent archaeological processing can be eliminated by grinding off the outer surfaces of the sherd prior to lipid extraction. In general, lipids are extracted from a sample by agitating it with chloroform-methanol (2:1). After the solvents are removed and the sample dried, the fatty acid, sterol or wax component is converted to methyl esters and/or ethers and run on the gas chromatograph.

7 Experimental Methods

In this chapter, the experimental procedures followed in this study are presented. These include the selection and processing of modern reference material, and, the preparation, decomposition and analysis of experimental cooking residues. The selection, processing and analysis of archaeological vessel residues are described, followed by the gas chromatography analysis parameters and the procedures used to correct for solvent contamination. Finally, the statistical analyses employed in the study are discussed.

7.1 Selection and Processing of Modern Reference Samples

Shay's (1980) compilation of Manitoba food plants together with historic and ethnographic accounts of diet were used to determine which samples to include in the reference collection. The collection consists of modern plant, mammal, bird and fish samples. Most plants samples were collected in Manitoba. Several berry samples were gathered from Wood Mountain, Saskatchewan. Seeds of varieties of corn, squash, sunflower and red bean used in the Middle Missouri villages were obtained from the University of North Dakota.

A number of plant species were collected from more than one vegetation zone. For each species collected in the field, one plant was pressed and others were stored in a cooler. Upon returning to the laboratory, samples to be analyzed were cleaned with distilled water then air dried at room temperature. If necessary, the identification of the pressed specimen was confirmed through comparison with those in the University of Manitoba herbarium. When different parts of the same plant were used at different times of the year, the fatty acid composition of the different sections of the plant were analyzed

separately (Appendix C).

Several mammal, bird and the catfish samples were donated for this study. Samples of bison, cow bone marrow and other fish were purchased commercially. Most of the fish and the cow bone marrow sample were analyzed fresh; other flesh samples were previously frozen.

Lipid Extraction of Modern Reference Material

The procedures for the extraction of lipids from modern reference material and the preparation of fatty acid methyl esters are those developed by Dr. Roman Przybylski, Department of Foods and Nutrition, University of Manitoba. Where possible, 10 g of the sample was taken. The sample was ground into a powder with an electric coffee grinder then placed in a homogenizer flask with 50 ml of methanol-chloroform in a 2:1 ratio. Following 2 minutes of homogenization (blending at high speed), the decanted solvent was filtered into a separatory funnel. The sample was homogenized at second time with an additional 50 ml of chloroform:methanol (2:1) for two minutes and the solvent filtered into the separatory funnel. Possible non-lipid contaminants, such as sugars, amino acids, urea and salts, were removed by washing the filtered solvent/lipid mixture with 33 ml of distilled water. The mixture separated into two layers; the upper consisted of mainly water, methanol and contaminants and the lower contained mainly chloroform and lipids.

The next day, the lower lipid-rich layer was drained from the separatory funnel into a round bottom flask which was then positioned in a heated water bath and the solvents evaporated under vacuum using a rotary evaporator. Any remaining water was removed at this time by the addition of 2 ml of benzene. The sample was then transferred to a 4

dram glass vial, of known mass. Another 2 ml of benzene was added and the sample placed in a heating block under a stream of nitrogen until no further weight loss due to solvent evaporation could be detected. The residue which remained in the vial was the total lipid extract, containing all of the triacylglycerides, sterols, waxes, phospholipids, *et cetera*, present in the original sample. Any lipid samples not processed immediately were stored under nitrogen in chloroform-methanol (2:1) in a vial sealed with a teflon-lined cap and placed in a freezer.

In order to produce fatty acid methyl esters, 1 ml of petroleum ether was mixed with approximately 200 mg of the total lipid extract until a mono-phase system developed. Methylation required the addition of 12 ml of 0.5 N anhydrous methanolic hydrochloric acid. The sample was mixed on a shaker and heated in a 65°C- 70°C oven for one hour. Periodic mixing continued through the heating process until a transparent, monophase system was obtained. If the sample was still "milky" after 15 minutes an additional 4 ml of methanolic HCl was added. When the sample had cooled to room temperature the methyl esters were isolated by adding 3 ml of *iso*-octane and a volume of distilled water, equal to one-half the volume of methanol solution used. A 0.5 ml sample of the fatty acid methyl esters in the upper *I*-octane layer was placed in a GC sample vial and crimp sealed with an aluminum cap with a teflon seal. If the sample was known to have a high fat content, it was first diluted with an additional 0.5 ml *iso*-octane.

7.2 Preparations of Experimental Cooking Residues

A total of nineteen experimental cooking residues were prepared for analysis. The cooking pots used in this experiment were 750 - 1000 ml in capacity constructed by hand

from commercial, slightly coarse, Raku clay then dried for 9 - 18 days at room temperature. Vessels were fired in an open hearth fuelled with scrap lumber which produced a fire that, on the basis of pyrometric cone deformation, exceeded 1000°C. This may be higher than normal for non-kiln-fired, unglazed vessels, like those utilized by the late Precontact inhabitants of Western Canada (Rice 1987:82). The experimental cooking vessels had pastes harder than an average Precontact pot.

The complete list of samples used in the cooking experiments is provided in Table 4. The selection of foods was based on historic and ethnographic accounts and Shay's (1980) compilation of Manitoba food plants. Previously frozen meat and fish samples were used; except for dried red beans and prairie turnip, fresh plant samples were used. For MR 1, distilled water was boiled in a vessel sealed with commercial lard; other cooking experiments were performed in vessels without any post-firing surface treatments. Food samples were boiled in distilled water over a wood fire for 1.0-1.5 hours, except for MR 17, dock seeds, which were dry parched.

Four days after cooking, a sherd from the neck or shoulder area of each vessel was collected and stored in the freezer. These samples are designated with the letter "a." After allowing the vessels to remain at room temperature for 80 days, two sets of sherds were collected. One set of sherds, designated with the letter "b", was placed in the freezer; the other set of sherds, "c", were placed in a 75°C oven for 30 days as a long term decomposition experiment. The beaver and cow bone marrow residues deteriorated for one day at room temperature followed by 30 days in a 75°C oven.

Table 4. Vessel area and sherd mass for experimental modern cooking residues.

Sample	Food Cooked in Water	Vessel Area	4 day (a)	Long Term (c)
MR1	H_20 with lard sealant	below shoulder	23.05g	11.55 g
MR2	Bison meat (65 g)	below shoulder	14.09 g	17.49 g
MR3	Corn (43 g)	below shoulder	13.44 g	13.84 g
MR4	Catfish (85 g)	below shoulder	11.93 g	14.15 g
MR5	Pike (70 g)	shoulder	18.36 g	17.19 g
MR6	Deer (100 g)	shoulder	12.50 g	8.15 g
MR7	False solomon's seal greens (80 g)	shoulder	9.03 g	9.71 g
MR8	Chokecherry (60 g)	shoulder	12.00 g	9.33 g
MR9	Fireweed greens (50 g)	shoulder	12.87 g	11.07 g
MR10	Cattail root (75 g)	shoulder	11.37 g	14.07 g
MR11	Corn (100 g) and Red Beans (100 g)	neck	12.05 g	12.96 g
MR12	Bison (100 g) and Corn (85 g)	neck / shoulder	14.38 g	15.71 g
MR13	Bison (120 g) and Chokecherry (80 g)	neck / shoulder	13.92 g	8.64 g
MR14	Deer (80 g) and Fireweed (50 g)	shoulder	18.47 g	15.98 g
MR15	Saskatoon (100 g) and Prairie turnip (120 g)	shoulder	15.65 g	19.75 g
MR16	Pike (90 g) and Chokecherry (90 g)	below shoulder	11.35 g	16.91 g
MR17	Parched Dock seeds (~ 40 g)	below shoulder	13.96 g	15.84 g
MR18	Beaver (33 g)	neck/shoulder	20.64 g	12.88 g
MR19	Cow Bone Marrow (~ 100 g)	shoulder	14.59	14.57 g

7.3 Selection of Archaeological Vessel Sherds

For this study, archaeological and experimental cooking pot sherds from the neck or shoulder area were analyzed, where possible. While sherds as small as 3 g were examined, on average, sherds weighed about 10 g. Sherds and residues were handled either with clean equipment or with gloved hands from the time the sherds were selected until they were processed. To reduce the level of contamination from plasticizers, the sherds were wrapped in Kimwipe ® tissues before being placed in plastic sample bags. While this protocol likely ensures the removal of contaminants present prior to processing, the sample may be contaminated in the laboratory by chemicals and solvents which themselves may contain low levels of fatty acids. When the original sample contains only a small amount of lipid, solvent contamination can affect its fatty acid composition. The procedures followed in this study for identifying and correcting for solvent contamination are discussed later in this chapter.

7.4 Lipid Extraction of Archaeological and Experimental Residues

A modified version of the procedure developed by Evershed *et al.* (1990) for archaeological pot residues was followed in this study. First, any surface contaminants were removed by grinding the exterior surfaces off the sherd with a Dremel ® tool fitted with a silicon carbide grinding stone. For the experimental cooking residue sherds and small, 4.0 g or less, archaeological sherds, surface contamination was removed by wiping the exterior with chloroform alone or chloroform and methanol (2:1). Immediately thereafter, the sherd was crushed with a hammer mortar and pestle designed for crushing minerals, and the powder transferred to a 10 dram screw-top glass vial. To prevent

decomposition, 10 ml of chloroform-methanol (2:1) was added, the vial sealed with a teflon-lined cap and stored in a freezer. Usually samples were processed the next day; if the lipid extraction was delayed more than 24 hours, the sample was stored under nitrogen.

The powder and solvents were transferred to an Erlynmeyer flask with an additional 40 ml chloroform-methanol (2:1) and placed in a ultrasonication water bath for 10 minutes. The decanted solvent was filtered into a round bottom flask and the extraction repeated with an additional 50 ml of chloroform-methanol (2:1). The solvents were evaporated under vacuum and heat from a water bath using a rotary evaporator. Any remaining water was removed by the addition of 2 ml of benzene. Small amounts of clay-sized particles which passed through the filter paper were removed from the total lipid extract with centrifugation. The "dry" lipid was transferred to a centrifuge vial in 1.5 ml of chloroform-methanol and spun for 10 min in a table top centrifuge. The supernatant, containing the total lipid extract, was transferred to a 4 dram screw-top glass vial with teflon cap seal and stored in a freezer.

Fatty acids were converted to methyl esters following procedures developed by Dr. Roman Przybylski, Department of Foods and Nutrition, University of Manitoba for micro-samples of lipids. Approximately 10-20 mg of the total lipid extract (between 100 and 700 µl of the total lipid extract/chloroform-methanol (2:1) solution) was placed in a screw-top test tube. The sample was dried in a heating block under a stream of nitrogen and 6 ml of 0.5 N methanolic-HCL was added. The sample was mixed on a shaker and heated in an oven at 70°C for one hour. Periodic mixing continued during the first 15

minutes of the heating process.

When the sample returned to room temperature, 3 ml of petroleum ether and 4 ml of distilled water were added. About 75% of the petroleum ether layer, containing the fatty acid methyl esters, was transferred to a vial and the extraction was repeated with an additional 3 ml of petroleum ether. The upper layers were combined and the sample dried in heating block under a stream of nitrogen. The methyl esters were transferred to a GC vial with a conical insert with 75 µl of *iso*-octane and crimp sealed with a teflon-lined aluminum cap. Where possible, 1 µl of the sample was injected for analysis. If the total sum of fatty acid peaks in the resulting chromatogram was less than 100,000 units, the amount of sample injected was increased to 3 µl and/or *iso*-octane was evaporated under nitrogen to increase the concentration.

7.5 Gas Chromatography Analysis Parameters

Two different columns were used in the analysis of the modern reference material. Samples M1-M5, processed in 1994, were injected onto a Polar Carbowax 20M fused silica capillary column (30 m X 0.25 mm I.D.). All other modern references, the experimental cooking residues and all archaeological residues, processed from 1995 to 1997, were injected onto a Supelcowax 10 fused silica capillary column (30 m X 0.25 mm I.D.). Samples were injected through a split injection system set at a 1-30 ratio and 88 kilopascals. Hydrogen was used as the carrier gas. Temperature programming was from 190°C to 235°C with the oven temperature increasing by 2°C each minute following an initial 3 minute isothermal hold. After the maximum column temperature of 235°C was reached, there was a second isothermal hold to clear out column impurities. For modern

references, the hold lasted from 5 to 17 minutes; the archaeological and experimental residues required a hold of only 0.5 to 1 minute.

If a deterioration of chromatographic performance was observed, column impurities were "burned out" with a one hour isothermal hold at 235°C. If the column had been used for other research projects, it was washed with solvent prior to continuing this analysis. By following the above outlined cleaning procedures, the need to use a retention gap to trap impurities before they enter the column is eliminated.

7.6 Purity Index

In cases where only a small amount of lipid was extracted from the sample, a useful chromatogram could only be obtained by a) increasing the amount of sample injected onto the column from 1μl to 3 μl, b) concentrating the sample by evaporating the *iso*-octane under nitrogen, or c) a combination of both. As the concentration of the samples increases, the potential for contaminants in laboratory solvents and chemicals to affect the sample composition increases, as well. The levels of lipid extracted from the modern reference samples were high enough to make the effect of solvent/chemical contaminants is negligible. In order to assess the impact of solvent/chemical contamination in archaeological and experimental residues, sample blanks were run. For the archaeological residues, the blank run consisted of the lipid extraction and methyl ester conversion using only solvents and chemicals. For the experimental residues, a sherd from an unused, hand-made pot underwent the lipid extraction and methyl ester conversion process. Traces of fatty acid contaminants were found in the benzene used to dry the samples.

A measure of the fatty acid contaminants in the blanks was determined using a purity index. First, the amount of solvent in the sample was calculated as follows:

$$\text{Solvent Amount} = \frac{\text{Volume of Lipid Extract}}{\text{Volume of Iso-octane}} \times \text{Volume Injected}$$

The purity index was determined by dividing the total integrated area of fatty acids under the chromatogram peaks, given as dimensionless units, by the amount of solvent in the injected sample:

$$\text{Purity Index} = \frac{\text{Total Integrated Area of Fatty Acids}}{\text{Solvent Amount}}$$

The purity index of the blank samples was then compared to that of the archaeological and experimental residues. All samples estimated or determined to have solvent contamination levels greater than 5% of the total fatty acid area were identified for correction. In the case of the experimental cooking residues, the amount of solvent in the injected sample was known so the level of contamination could be accurately determined. The fatty acid-to-solvent ratio of the blank was simply adjusted to match that of the cooking residue sample and the contamination peaks were subtracted. Only the relative fatty acid-to-solvent ratio of archaeological residues was recorded so it was necessary to completely reanalyze these samples (Table 5). Fatty acid methyl esters were again converted from the total lipid extract and rerun on the gas chromatograph. If the total lipid extract had decomposed since the time of initial processing or the level of contamination was so high it made the chromatogram unusable, the sample was excluded from the analysis. Two samples from Cabin Point, CabPt10 and CabPt12, and two from Stott, Stott2 and Stott17, were excluded from the study for this reason.

Table 5. List of archaeological residues corrected for solvent contamination.

No.	Site	Vessel Area	Mass		No.	Site	Vessel Area	Mass
VR9	Sand4	rim	3.85 g		VR11	Sand5b	neck	6.49 g
VR13	Sand6b	body	6.14 g		VR71	Asch14	body	6.64 g
VR77	LkMid2	neck/ should	10.00 g		VR78	LkMid3	neck	15.34 g
VR104	CabPt13	neck	12.96 g		VR105	CabPt14	neck	11.35 g
VR106	CabPt15	body	9.76 g		VR107	CabPt16	body	7.76 g
VR120	Stott12	body	8.65 g		VR131	Hartley6	body	8.73 g
VR132	Hartley7	rim	4.76 g		VR135	Hartley10	body	5.06 g
VR148	Bush8	body	8.59 g		VR161	Lebret1	body	13.75 g
VR164	Lebret5	body	6.42 g		VR165	Lebret6	body	8.80 g
VR166	Lebret7	body	6.55 g		VR168	Lebret9	body	5.52 g
VR169	Lebret10	body	8.77 g		VR174	LngJn3	body	7.19 g
VR189	Sjovold4	neck	4.86 g		VR193	Garratt4	body	3.10 g
VR199	Garratt10	body	5.81 g		VR213	Lvstrm3	neck	4.36 g

7.7 Methods of Characterizing the Fatty Acid Compositions

In this study, the fatty acid compositions of modern references and Precontact vessel residues are characterized by statistical methods, in particular hierarchical cluster and principal component analyses. These methods are objective and able to process the high number of variables resulting from fatty acid analysis; nearly 40 fatty acids were present in some modern references; ten fatty acids were regularly detected in the archaeological residues. Furthermore, the results of the hierarchical cluster analysis can be independently verified by principal component analysis. These methods provide a

framework for presenting the data.

7.8 Cluster Analysis

Cluster analysis is a type of numerical classification similar to biological taxonomy in that groupings are based on the state or value of attributes which vary significantly between individuals. Numerical classifications represent internally consistent processes which can establish order in a data set consisting of a large number of items described in terms of a large number of variables. The various methods will, to different degrees, impose clusters on the data set so users of this technique must take care in selecting the specific clustering processes and variables to be considered. Cluster analysis is a process which provides a measure of similarity between the individual members of a data set. Individuals are grouped in such a manner that the members of a group are more similar to each other than to non-members; intragroup similarity is higher than intergroup similarity. The technique applied in this study is a hierarchical agglomerative cluster analysis. Initially, all samples under consideration are separate. Groups of samples are formed on the basis of highest (or highest remaining) similarity between individual samples and/or groups. The members of the first group are the most similar individuals in the entire data set. Grouping continues at increasingly lower levels of similarity until all the individuals are clustered together in one group which possesses a very low level of similarity. In order to be included in a group, an individual must have a specific level of similarity to a member or all members of the group. An individual may be compared to any member of a group (nearest neighbour), the member of the group from which it is most dissimilar (farthest neighbour), or each member of the group (average linkage) (Shennan 1988:213-

216). Because these different methods may produce different clustering results, hierarchical cluster analysis provides only a quick approximation of grouping tendencies (Bishop and Neff 1989:66-67). The data should be analyzed independently with a multivariate technique, such as principal component analysis (Sec. 7.9).

The relationship between individuals is expressed by similarity or distance measures, usually an Euclidian distance coefficient. Shennan (1988:197-198) explains that when considering two individuals, *i* and *j*, measured in terms of a number of variables, p, the Euclidean distance coefficient d_{ij} is defined as:

$$d_{ij}=\sqrt{\sum_{k=1}^{p}(x_{ik}-x_{jk})^2}$$

In simple terms, the distance between two individuals is the square root of the sum of the differences of each variable which describes the individuals. This distance is referred to as the normalized root-mean-square distance (RMS) by the cluster analysis employed in this study. If the values of the variables which describe two individuals are similar, the normalized RMS distance will be very small. Two very dissimilar individuals will have variable values with large differences, resulting in a large RMS distance. In order to use an Euclidean distance coefficient, all of the variables which describe an individual must be independent of one another. For this reason, the distances are not calculated from the original values but from those transformed through multivariate analysis which, by definition, ensures their independence by preserving variance but eliminating covariance (Shennan 1988; Bishop and Neff 1989). The values calculated are

presented in a full n x n matrix, where n is the number of individuals being studied.

A hierarchical method of cluster analysis will order the members of the data set to show they are similar at different levels. The relationships between the individuals and/or groups are illustrated in a tree diagram or dendrogram, where the level of similarity between individuals or groups corresponds to the root-mean-square distance at which the various clusters form. For exploratory purposes, the method used to join the individuals into clusters in this study is known as average linkage cluster analysis. Two individuals are compared by calculating the arithmetic average of the distance between them. Two groups are compared by calculating the arithmetic average of the distance between each member of the first group paired with each member of the second. At each stage of the analysis, the distances between groups and/or individuals are calculated and the pair with the smallest distance are linked together.

7.9 Principal Component Analysis

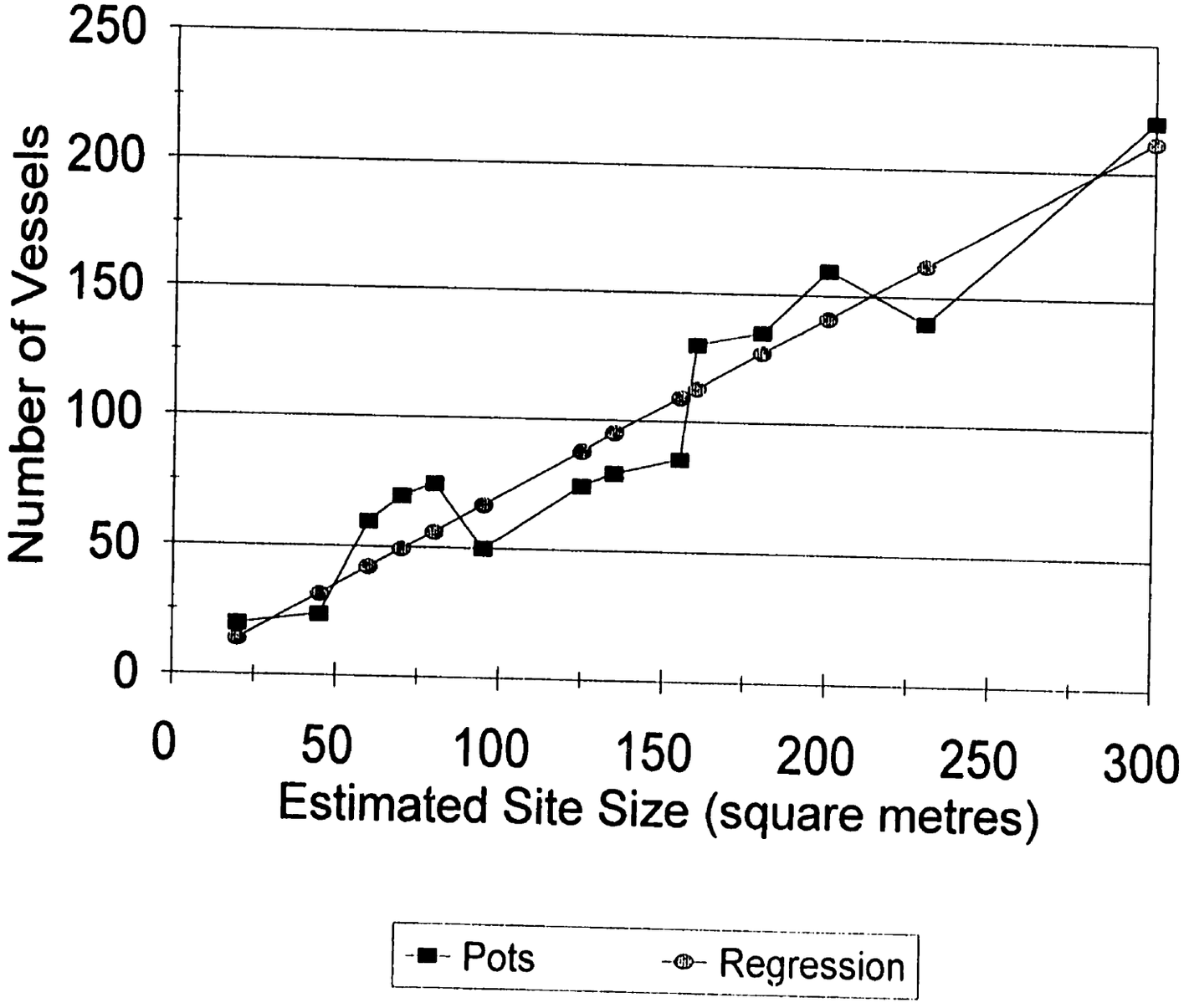
Principal component analysis, like other types of multivariate analysis, uses an ordination approach. It compresses the information contained in a large number of variables into a much smaller number of new variables, usually only two or three (Shennan 1988:242-243). The advantage of reducing the number of variables becomes clear when many variables are required to describe each member of the data set. As a general rule, the number of dimensions required to properly plot a point, representing a member of the data set, is equal to the number of variables used to describe it. When only two variables, for example, the number of cooking pots recovered and site size, are used to describe each member, a two-dimensional scattergram of the entire data set can be made (Figure 8). A

point representing each member of the data set can be plotted against one axis representing site size and another representing number of pots. If ten variables are used to describe each member of the data set, however, visualizing or graphing the relationships between them becomes impractical.

The new variables produced by principal component analysis represent common factors "pulled out" from a number of different variables (Shennan 1988:245). The new variables contain all of the original information so relationships between the members of the data set can then be assessed through two-dimensional scattergrams. In particular, clusters of points appearing in the scattergrams indicate close relationships. In this respect it is similar to cluster analysis but principal component analysis differs in that it does not "force" the data into groups. Principal component analysis is similar to regression analysis in that it is used to examine trends in variation and assess the importance of a particular variable; however, there is no assumption of dependence or independence among the variables. A measure of correlation between each variable and every other is calculated then the resulting matrix is analyzed. Correlation between two variables, x and y, is calculated using the following equation where n is the number of variables, and σ_x and σ_y are the standard deviations of the x and y variables, respectively:

$$\frac{\frac{\sum(x-x)(y-y}{n}}{\sqrt{\sigma_x\sigma_y}}$$

Figure 8. Plot of number of pots versus site size with regression analysis.



Principal component analysis uses the matrix of correlation coefficients to produce a new set of independent variables. Similar to the way in which a mean number describes a number set, principal component analysis produces a mean variable which is closest to all the original variables in the analysis.

Principal component analysis has a strong theoretical foundation in statistics and linear algebra so only a sketch of how it works is provided. Principal component analysis is similar to regression analysis except that it operates in multiple dimensions. Regression analysis, a more familiar technique, provides a method of describing the relationship between a dependent and an independent variable. Data points can be plotted in a scattergram along two axes, as in the example of the number of pots and site size. Regression analysis provides a way to describe the relationship between the number of pots, identified by the variable y, and site size, identified by the variable x, as a straight line which represents an average of the data (Figure 8). The relationship between the data points is the mathematical expression of the line, $y = mx+b$, where m is the slope and b is the point at which the line intercepts the y-axis. Regression analysis also calculates a correlation coefficient, r, which tells us the degree to which the line "fits" or explains the data set. A good fit explains much of the variation, or we can say it reduces the variation. The square of this correlation coefficient, r^2, is the coefficient of determination; when multiplied by 100 it provides a percentage value of the fit. In this fictional example, site size explains 90.84% of the variation in the number of pots found at a given site.

Principal component analysis is similar to regression analysis, but it is used when there are many variables and many dimensions. Because there are more than two

dimensions, averages of the data must be expressed as vectors, lines that have specific orientations in space. These vectors are the principal components. The principal component vector is described in terms of the component loading, L, on each variable, which is analogous to the slope in regression analysis. If there are four variables, x_1 to x_4, the values for each variable are first normalized by subtracting it from its mean and dividing the difference by its standard deviation:

$$z_1 = \frac{x_1 - \overline{x_1}}{s_1}$$

The sum of the product of the component loading and the normalized values are the principal component scores. The equation for calculating for the first principal component score, PRIN1 is:

$$\text{PRIN1} = L_1z_1 + L_2z_2 + L_3z_3 + L_4z_4$$

The fit of the principal component can be assessed by examining its eigenvalue. When divided by the number of variables under consideration and multiplied by 100, the eigenvalue provides a percentage of the amount of variation the principal component explains. The analysis is performed on normalized variables to eliminate the effects of scale or, in the case of fatty acid composition analysis, to counteract the effects due solely to variation in the abundance of a fatty acid in nature (Bishop and Neff 1989). For this reason, the value of the component loading also indicates the explanatory value of each variable within the principal component (Bishop and Neff 1989). Variables with high component loadings account for more variation than those with low component loadings.

Because the relationships between the variables are usually highly complex, one principal component can not explain the majority of the variation. Instead of stopping here, a second principal component is generated to reduce the remaining variation, then a third and a fourth. While the number of principal components produced is equal to the number of variables, not all are useful. If most of the variation is explained by the first two or three principal components, only they need to be considered. In this study, only principal components with eigenvalues greater than or equal to 1 are considered significant.

Hierarchical cluster analysis is a technique used to identify grouping tendencies in the data. Results are presented as a dendrogram where degrees of greater or lesser similarity between individuals and groups of individuals are represented in a hierarchical fashion. While the results are presented in a manner which is very easy to understand, the criteria used to form clusters are user-defined. Principal component analysis provides a more objective, multivariate method of examining the data which can be used to identify clustering in the data without any attempt to force them into groups. By employing both methods, the relationships between individual members of the data set can be compared independently.

Chapter 8 - Results of the Analyses

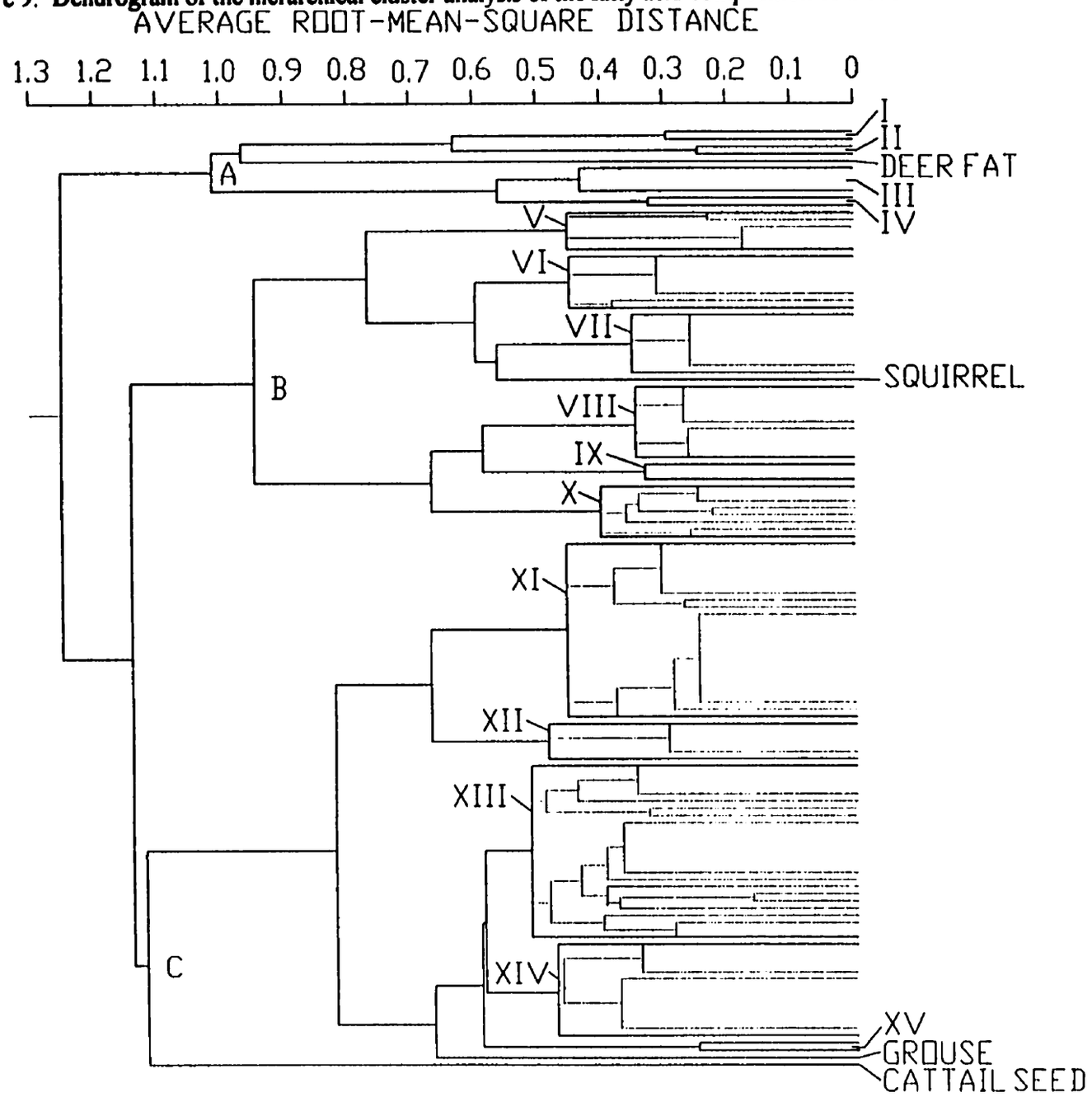
The results of the fatty acid composition analysis are accurate to two decimal places and presented in Appendix D. For ease of reading, values presented in the text are rounded to the nearest whole percent.

8.1 Modern References

The fatty acid compositions of modern references were subject to cluster analysis to assess the level of similarity between samples. The dendrogram, presented in Figure 9, shows there are three major clusters A, B and C, each consisting of a number of smaller clusters. Four samples, M2 deer fat, M59 cattail seeds, M131 grouse and M134 squirrel do not readily cluster with any other samples; they remain single entities until the RMS distance exceeds 0.50. Each of the major subclusters identified in the diagram is characterized in general terms below. The detailed fatty acid compositions of each sample associated with the subclusters is presented in Appendix D. These values are presented as relative percentages.

As discussed in detail below, the clusters which developed reflect broad similarities in the fatty acid composition of its individual members. Cluster A contains all large mammal samples, which are higher in C16:0, C18:0 and C18:1, and fish samples, which are high in very long chain polyunsaturated fatty acids (VLCP). Cluster B contains primarily plant seeds and berries samples but some plant roots and three small mammal samples, beaver, muskrat and squirrel are also included. These samples are similar in that they tend to have high levels of 18:1 and C18:2. The samples in cluster C include mostly plant greens and roots but some berries, grouse and cattail seed appear. These samples

Figure 9. Dendrogram of the hierarchical cluster analysis of the fatty acid composition of modern foods.



have higher levels of C18:2, C18:3 and/or very long chain saturated fatty acids (VLCS).

Cluster A is the large mammal and fish cluster which includes eleven samples. It consists of four subclusters, I to IV, and one sample that does not readily cluster, M2 deer fat, which all link at an RMS distance of 1.01. Subcluster I includes bear fat and cow bone marrow which join at an RMS distance of 0.29. The samples are similar in that they both have extremely high levels of C18:1w9, averaging 55%. The average levels of C16:0, at 20%, C18:0, at 7%, and C18:2, at 7%, are also significant. Other fatty acids do not appear at levels greater than 3%. Subcluster II includes the meat of two herbivores, bison and deer, and joins at a RMS distance of 0.24. The average fatty acid composition of these samples is characterized by high levels of C18:1w9 (36%), C18:0 (20%), C16:0 (19%) and C18:2 (9%). All other fatty acids present appear at levels less than 3%. Subclusters I and II link at a RMS distance of 0.63 then sample M2, deer fat, joins them at a RMS distance of 0.96. It differs from the other samples in terms of its higher level of C18:0 (39%) and lower level of C18:1w9 (21%).

Fish samples appear in subclusters III and IV, which all link together at a RMS distance of 0.56. Subcluster III forms at an RMS distance of 0.43 and includes pickerel, perch, catfish and smoked trout; subcluster IV forms at 0.32 and contains whitefish and smoked goldeye. The division between the two subclusters reflects higher levels of C18:1w9 and lower levels of C22:6 in whitefish and smoked goldeye, as compared to the other fish samples. The average fatty acid composition of the fish samples is characterized by high levels of VLCP, 41% for subcluster III and 25% for subcluster IV. Levels of C18:1 isomers are also quite high in fish samples, 18% for subcluster III and 32% for

subcluster IV. The average level of C16:0 isomers in the subclusters is about 15%; the average level of C16:1 is 8% for subcluster III and 12% for subcluster IV. Average levels of C18:0, C18:2 and C18:3 range from about 3 to 4%. Other fatty acids represent 2% or less of the composition.

Cluster B consists of six subclusters of seeds, berries, roots and small mammals, V-X, and one sample that does not readily cluster, M134 squirrel. In total, 46 samples appear in this group, which joins at a RMS distance of 0.95. Subcluster V is a small cluster (n=6) of chokecherry, pin cherry and wild hazelnuts in two minor clusters. The average fatty acid composition of these samples features very high levels of C18:1w9 (54%) and C18:2 (38%). The average level of C16:0 in the samples is 4%; all other fatty acids appear at levels less than 2%. The two minor clusters within subcluster V reflect variations in the levels of C18:1 and C18:2 among the samples; they link at a RMS distance of 0.45.

Subcluster VI contains samples of dock (n=3) and knotweed (n=1) seeds, two varieties of mushroom, acorn and beaver in two minor clusters. The average fatty acid composition of the samples in subcluster VI contain high levels of C18:2 (36%) and C18:1w9 (34%). The average level of C16:0 is 12%; amounts of C18:0, C18:3 and C24:0 range from 2% to 4%. All other fatty acids appear at levels less than 2%. The two minor clusters, which join at a RMS distance of 0.45, appear to reflect differences in the levels of C18:2 and C18:3.

Subcluster VII consists of a tight cluster of eight seeds and berries, including corn, sunflower, squash, bulrush, saskatoon and hawthorn, which join at a RMS distance of

0.26; this minor cluster then links with a pincherry sample at 0.35. The average fatty acid composition of these samples is characterized by very high levels of C18:2 (55%) and C18:1 (29%). Average amounts of C16:0 and C18:0 are 7% and 3%, respectively. The pincherry sample differed from the others in terms of its relatively lower C16:0 and higher C18:1 levels.

Subcluster VIII consists of ten plant roots, including false solomon's seal, cow-parsnip, Jerusalem artichoke, wild onion, prairie turnip, tiger lily, water-parsnip and wild calla, as well as a sample of vetchling pods in two minor clusters. The average fatty acid composition of the samples is characterized by high levels of C18:2 (49%) and C16:0 (20%). The levels of a number of other fatty acids are significant, including C18:3 (7%), C18:1 (5%), C24:0 (4%), C22:0 (3%) and C18:0 (3%). All samples join at a RMS distance of 0.34.

Subcluster IX is a small cluster of marsh-elder (n=1) and arrow-grass (n=2) seeds. The seeds have an average fatty acid composition which is very high in C18:2 (64%), with lower levels of C18:1 (10%), C16:0 (8%), C18:3 (5%) and C18:0 (4%). Other fatty acids appear at levels less than 3%. The samples link at a RMS distance of 0.33.

Subcluster X contains mainly plant material, dock and lamb's-quarters seeds and gooseberry, blueberry and juniper berries, but muskrat also appears. This subcluster contains a number of minor clusters; the eight samples link rather loosely at an RMS distance of 0.40. The average fatty acid compositions are quite variable; in general, the average level of C18:2 is high (39%) and significant amounts of C18:3 (20%), C18:1 (15%) and C16:0 (10%) are present. Other fatty acids appear at average levels less than

3%.

Within Cluster B, subclusters V, VI, VII and sample M134 squirrel all join at a RMS distance of 0.77. Squirrel likely appears in cluster B due to its high levels of C18:2. Subclusters VIII, IX and X are more closely related, joining at a RMS distance of 0.67.

Cluster C consists of five subclusters of plants, XI to XV, and two samples that did not readily cluster, M131 grouse, and M59 cattail seed for a total of 74. Subcluster XI is dominated by plant greens, specifically false solomon's seal, fireweed, golden rod, violet, dock and lamb's-quarters which form two minor clusters. In total, there are 25 plant samples, 22 of which are plant greens, 2 seeds and one plant root. The average fatty acid composition of the samples is characterized by high levels of C18:3 (35%) and C16:0 (19%). The two minor clusters within subcluster XI reflect differences in the average levels of C16:1 and C18:2. Stinging nettle and sarsaparilla greens were the last two samples to join established clusters; all members of the subcluster link at a RMS distance of 0.45.

Subcluster XII consists exclusively of rosehips and bearberries. The average fatty acid composition of these samples is characterized by high levels of C18:3 (40%), C18:2 (29%) and C18:1w9 (15%). Three fatty acids have levels of about 3%: C16:0, C17:0 and C22:0. All other fatty acids appear at levels of 1% or lower. Five of the six samples cluster at a RMS distance of 0.30. One bearberry sample differed from the others in terms of its higher levels of C22:0 and C24:0, which are both VLCS, and lower levels of C18:1w9 and C18:2. It does not join the other samples in this cluster until a RMS distance of 0.49.

Subcluster XIII is dominated by plant root samples, including bulrush, cattail, waterparsnip, giant reed, fireweed, sarsaparilla, water-hore hound, wound wort, ostrich fern and Jerusalem artichoke. Nineteen of the 25 samples in subcluster XIII are roots; red osier and saskatoon berries, mare's tail and chickweed greens, and lamb's-quarter and dock seeds also appear. The members of this subcluster are rather loosely linked, consisting of a number of minor clusters which join at a RMS distance of 0.51. The fatty acid composition of samples is variable. Average levels of C18:2 (26%) and C16:0 (23%) are quite high, but there are significant amounts of VLCS (16%), C18:1 (12%), and C18:3 (10%), as well. Other fatty acids occur at levels of about 3% or less.

Subcluster XIV is dominated by plant greens, including cow-parsnip, cattail, bulrush and golden rod. Twelve of the 14 samples in this cluster are plant greens; the other samples are silverberry and arrowhead roots. The average fatty acid composition is characterized by a high level of C16:0 (25%) with moderate levels of VLCS (19%), C18:3 (18%) and C18:2 (16%). The average levels of C16:1, C18:1 and C18:0 range from 7% and 4%; other fatty acids occur at levels less than 3%. All samples in subcluster XIV link at a RMS distance of 0.47.

Subcluster XV contains two samples of cattail root, which link at a RMS distance of 0.25. The average fatty acid composition of these samples is characterized by very high levels of VLCS; together C24:0 (19%), C22:0 (13%) and C20:0 (12%) account for almost 45% of all fatty acids. Significant levels of C16:0 (19%) and C18:2 (16%) are also present. While C18:0 occurs at 6% and C18:3 at 3%, all other fatty acids occur at levels less than 3%.

Within cluster C, subcluster XI is most closely related to subcluster XII and they join at a RMS distance of 0.67. Subclusters XIII, XIV and XV are quite closely related and join at a RMS distance of 0.59. Sample M131 grouse, joins the latter group at a RMS distance of 0.67. The grouse sample is likely included in cluster C because its fatty acid composition is characterized by a number of fatty acids, C16:0, C18:0, C18:1, C18:2, occurring at levels between 13% and 18%, rather than one or two dominant fatty acids. Sample M59 cattail seeds joins cluster C at a RMS distance of 1.12; it differs from the other samples on the basis of its high level of 17:0, 20%.

The discriminating characteristics of the modern reference sample clusters are summarized in Table 6. Modern reference samples in cluster A, the large herbivore and fish cluster have elevated levels of C16:0 and C18:1. Bison and deer samples have higher levels of C18:0 while fish has high levels of VLCP. Samples of caribou and moose were not available for this study but the fatty acid composition of these foods have been determined by Appavoo *et al.* (1991). Both are very similar to bison and deer, but differ in that the level of C16:0 is slightly higher and the C18:1 level is slightly lower. Every type of sample, other than plant greens, appears in cluster B; berries, seeds, nuts, and small mammals are most common. These samples have high to extremely high levels of C18:2; samples in subclusters VIII, IX and X have high to extremely high levels of C18:1, as well. Squirrel is loosely linked to the above cluster but differs in terms of its higher level of VLCP. Modern reference samples in cluster C are mainly plant roots and greens, but include rosehips and bearberries. The grouse sample is loosely linked to this cluster. These samples all have higher levels of C18:2. Except for the berries, all samples have

Table 6. Summary of Average Fatty Acid Compositions of Modern Reference Clusters

Cluster	Subcluster	Type	16:0	18:0	18:1	18:2	18:3	VLCS	VLCP
A	I	Fat	MH	L	E	L	tr	tr	tr
	II	Meat	MH	MH	H	M	tr	tr	L
		Deer Fat	MH	VH	MH	L	tr	tr	tr
	III	Fish	MH	L	MH	tr	L	tr	VH
	IV	Fish	M	tr	H	L	L	tr	MH
B	V	Berries & Nuts	L	tr	E	H	tr	tr	tr
	VI	Mixed	M	tr	H	H	L	L	tr
	VII	Seeds & Berries	L	tr	H	E	tr	L	tr
		Squirrel	M	L	MH	VH	tr	tr	MH
	VIII	Roots	MH	tr	L	VH	L	M	tr
	IX	Seeds	L	L	MH	E	L	L	tr
	X	Mixed	M	tr	M	VH	MH	L	tr
C	XI	Greens	MH	tr	L	MH	H	L	tr
	XII	Berries	L	tr	M	H	VH	M	tr
	XIII	Roots	MH	L	M	H	M	MH	tr
	XIV	Greens	MH	L	L	MH	MH	MH	tr
	XV	Roots	MH	L	tr	MH	L	VH	tr
		Grouse	MH	M	MH	MH	L	tr	MH
		Cat tail seed	M	L	L	M	L	VH	tr

Legend: tr = 0-2.99% L = 3.0-7.99% M = 8.0-14.99% MH = 15-25.99%
H = 26.0-37.00% VH = 38.0-49.99% E = ≥50%

elevated levels of C16:0; higher levels of C18:3 and/or VLCS are common. Grouse differs from the other samples in this cluster because of its higher levels of C18:1 and VLCP. Cattail seeds are different from the other samples due to its high levels of C17:0 and VLCS. The dendrogram complete with the categories of foods appearing in each subcluster indicated is presented in Figure 10.

When all 37 variables are included in the analysis, each principal component explains a relatively small part of the variation. The first eleven principal components have eigenvalues greater than one and are considered significant. Together they account for 76.61% of the total variation in the modern reference material. Principal component 1 accounts for 22.24% of the variation, principal component 2 explains 11.8%. Principal components 3 to 11 explain from 8.65% to 2.85% of the variation (Table 7).

The component loadings on polyunsaturated fatty acids are high in the first principal component resulting in the separation of fish and grouse in the plot of PRIN2 vs. PRIN1 (Figure 11). Greens, roots as well as, seeds and berries, each form fairly tight clusters in the plot of PRIN2 vs PRIN3; these clusters are delineated with dashed lines (Figure 12). The distinction between the large mammal meat and fat samples and the rest of the reference material is most apparent in the plot of PRIN5 vs. PRIN6; these samples have high negative loadings on saturated fatty acids (Figure 13). Reducing the number of variables under consideration would simplify the principal component analysis, but this action may also introduce an unacceptable level of bias.

Figure 10. Dendrogram of the hierarchical cluster analysis of the fatty acid composition with subclusters identified.

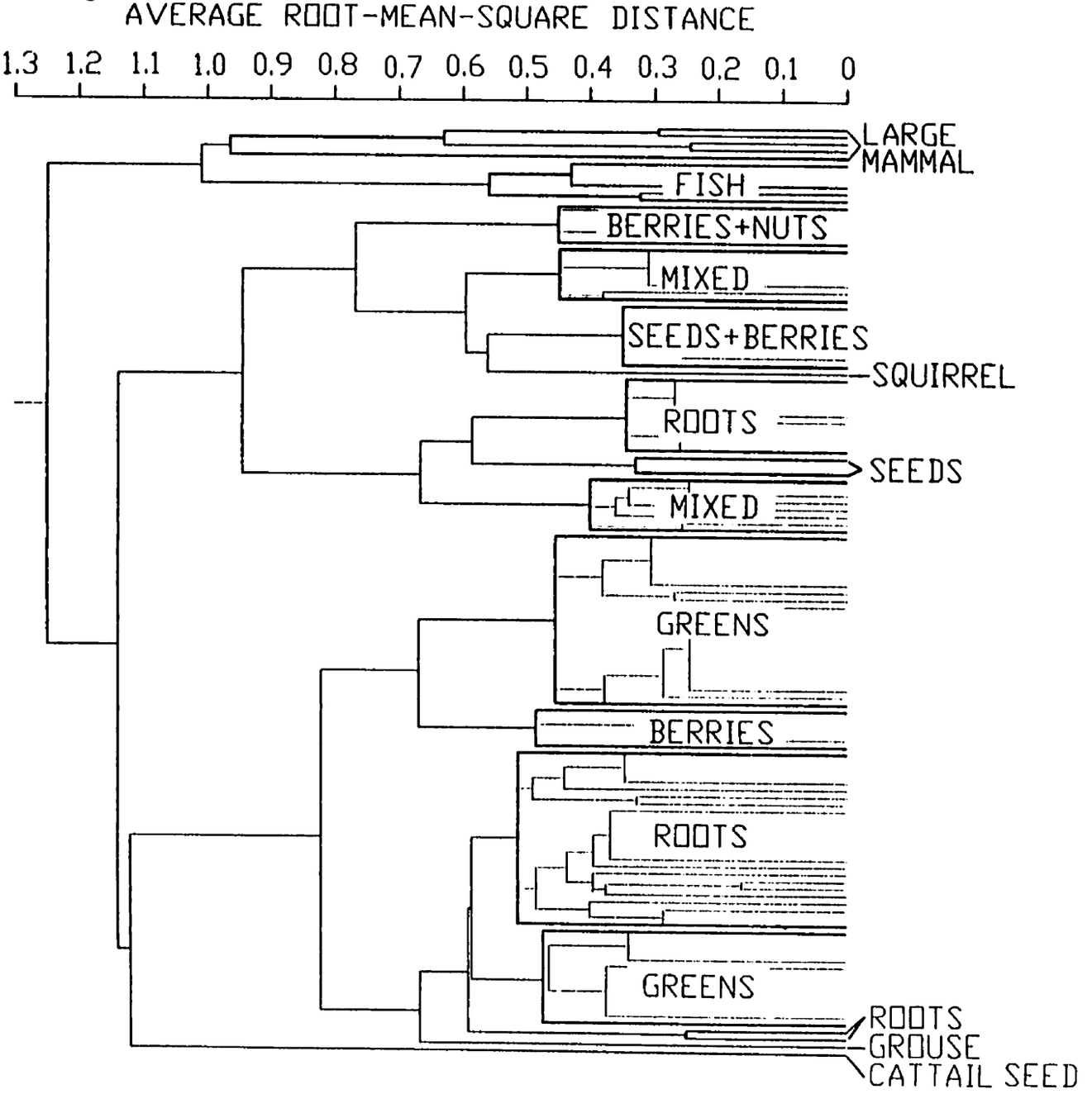
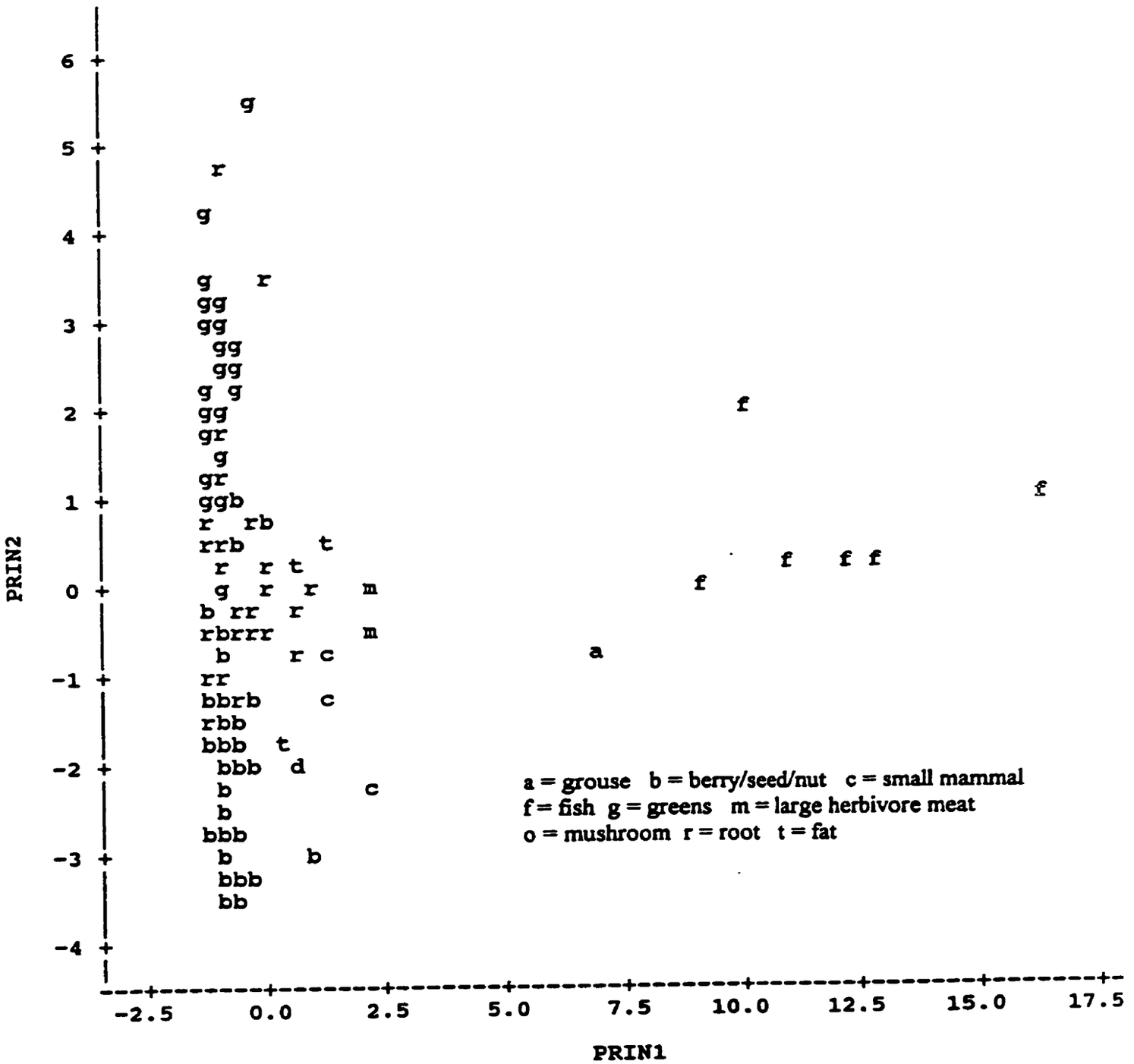


Table 7. Variation in Modern References Explained by Principal Components 1 to 11

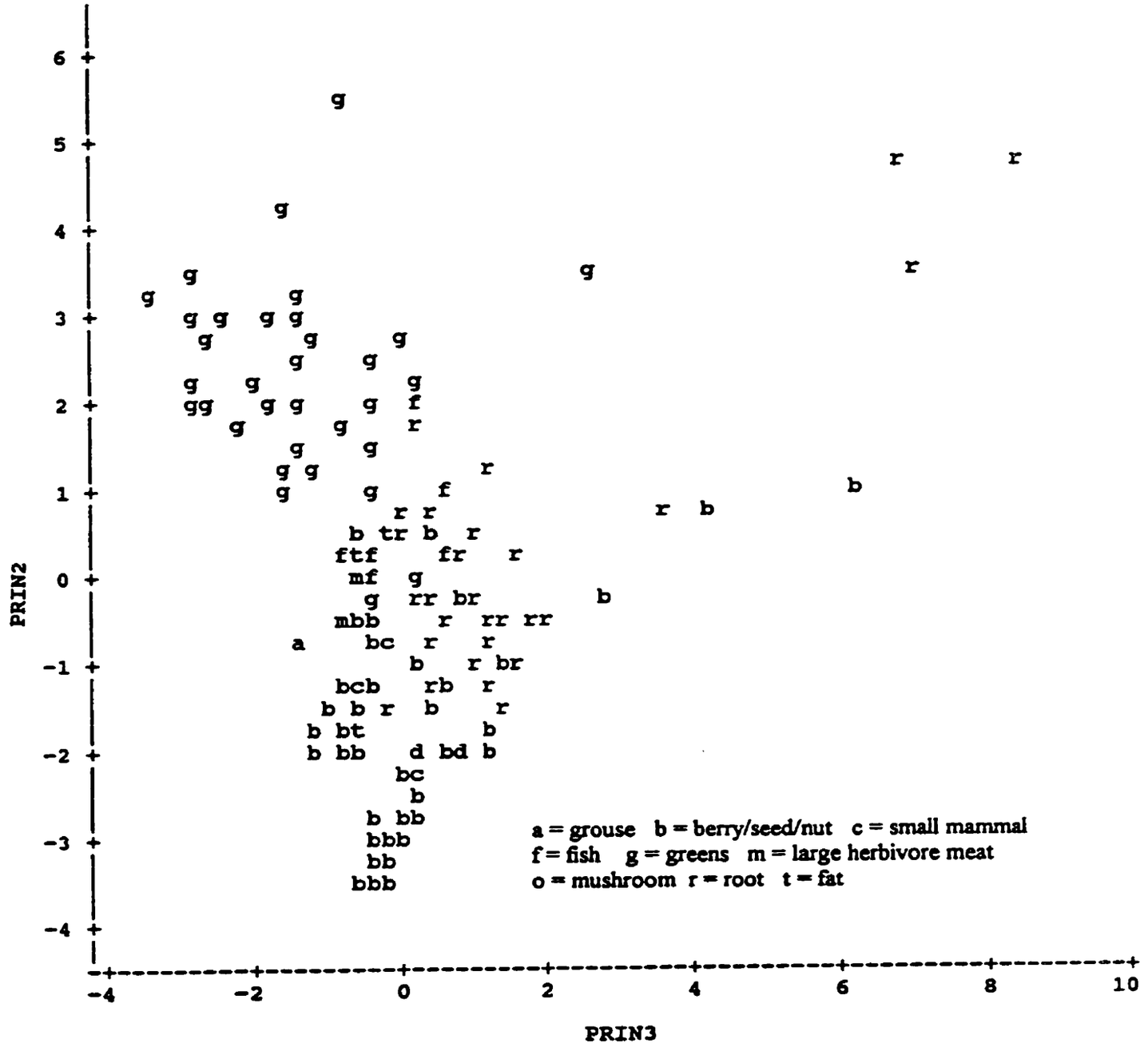
Principal Component	Eigenvalue	Fatty Acids with High Component Loadings	Percentage Variation	Cumulative Variation
PRIN1	8.01	Polyunsaturates	22.24	22.24
PRIN2	4.25	C18:1; C18:2	11.80	34.04
PRIN3	3.12	Medium chain	8.66	42.71
PRIN4	2.50	C17:0; C19:0	6.93	49.64
PRIN5	1.87	Unsaturates	5.19	54.84
PRIN6	1.72	C16:0; C17:0; C18:0	4.78	59.61
PRIN7	1.45	C18:3w6, C18:4	4.03	63.64
PRIN8	1.44	monounsaturates	3.99	67.63
PRIN9	1.15	C17:1; C20:2; C20:4w6	3.19	70.82
PRIN10	1.06	C20:1; C22:1	2.93	73.75
PRIN11	1.03	C14:1; C18:1w11; C20:4w6	2.86	76.61

Figure 11. Plot of PRIN2 scores versus PRIN1 scores for the Modern References



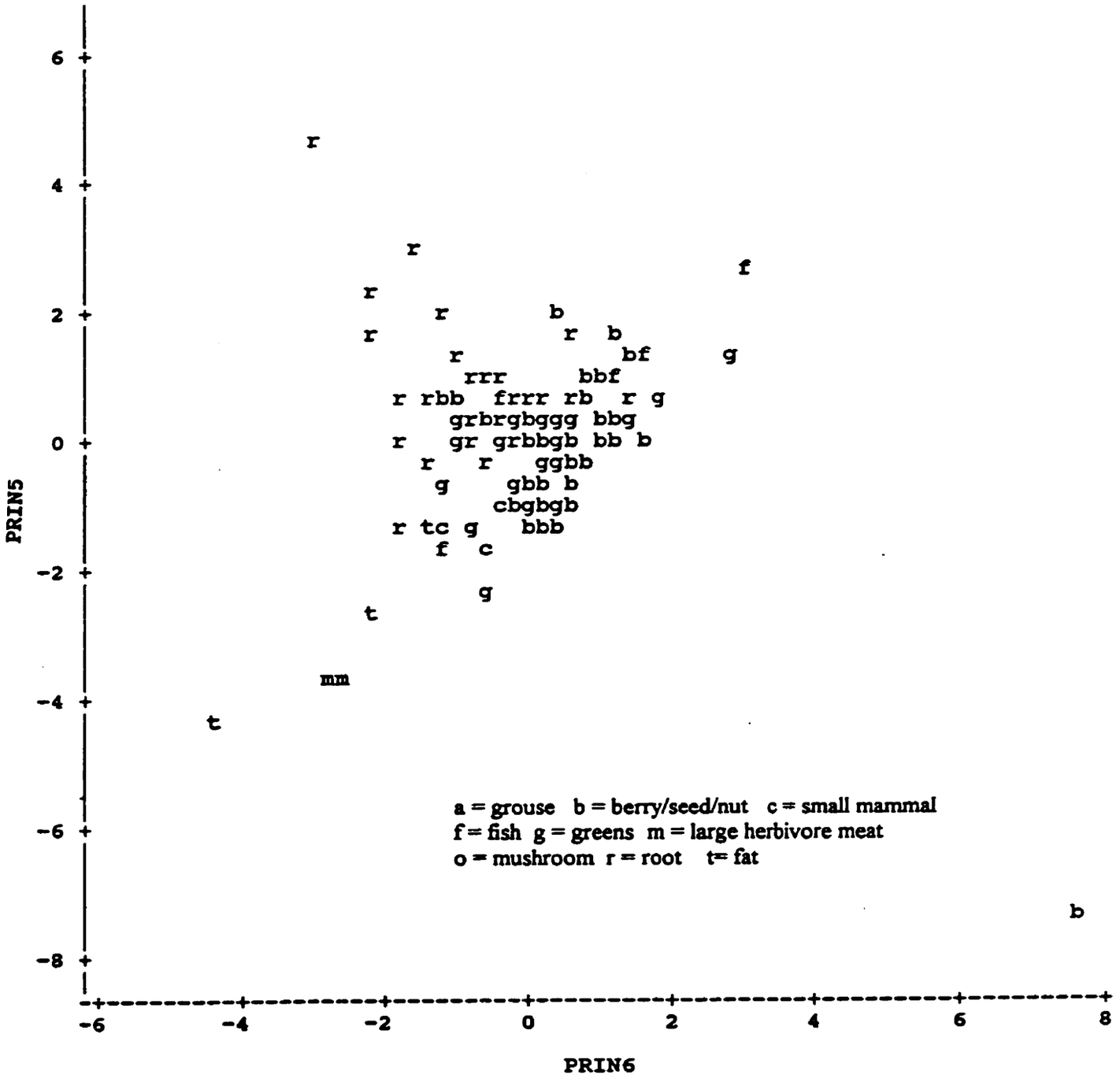
NOTE: 41 obs hidden.

Figure 12. Plot of the PRIN2 scores versus PRIN3 scores for the modern references.



NOTE: 15 obs hidden.

Figure 13. Plot of the PRIN5 scores versus PRIN6 scores for the modern references.



NOTE: 44 obs hidden.

8.2 Experimental Cooking Residues

Three sets of sherds were collected from the vessels used in the cooking experiments and placed in the freezer after a period of decomposition: the "a" and "b" sets were left at room temperature for 4 and 80 days, respectively; the "c" set was left at room temperature for 80 days then placed in a 75°C oven for 30 days to simulate long term decomposition. Because of the high level of similarity in the fatty acid compositions of the "a" and "c" sets, it was deemed unecessary to analyze the "b" set. The results of the analysis of experimental cooking residues are presented in Table 8. Lipids were extracted from all samples but MR11, the residue for cooked corn and beans, was excluded from the analysis because only small amounts of fatty acids remained after correction for solvent contamination. Bar graphs comparing the fatty acid composition of eleven uncooked samples with those after 4 day and long term decomposition are presented in Appendix E. Bar graphs showing only the 4 day and long term decomposition results are provided for the remaining residues.

The analysis of the experimental cooking residues shows that thermal and oxidative decomposition rapidly reduces the number and amount of fatty acids in a sample. In general, the deterioration of polyunsaturated fatty acids was the most rapid. Four days after cooking, both saturated and unsaturated fatty acids with chain-lengths of 20 or more carbons were no longer detectable. The only polyunsaturated fatty acids remaining after 4 days were C18:2 and C18:3. Due to the lower lipid concentrations in these samples, the two C18:1 isomers do not separate clearly in all cases so their sum is presented. The amount of C18:1 isomers (C18:1s) dropped substantially over the period of decomposition

Table 8. Results of the fatty acid analysis of the "a" and "c" sets of experimental cooking residues.

Food	No.	12:0	13:0	14:0	14:1	15:0	15:1	16:0	16:1	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3w3
Lard sealant	MR1a	0.11	0.00	1.60	0.00	0.08	0.04	24.81	2.58	0.43	0.40	13.75	40.48	3.61	11.48	0.00	0.00	0.63
Lard sealant	MR1c	0.20	0.00	2.97	0.00	0.23	2.67	48.87	1.42	0.89	0.61	25.68	14.10	1.75	0.42	0.00	0.00	0.19
Bison	MR2a	0.10	0.02	2.30	0.13	0.50	0.04	17.77	2.02	1.24	0.57	26.13	42.78	1.50	4.26	0.00	0.10	0.54
Bison	MR2c	0.30	0.16	5.31	0.00	0.98	2.97	29.61	1.79	1.88	0.84	36.97	18.01	0.00	0.67	0.00	0.14	0.37
Sweet Corn	MR3a	0.00	0.00	0.71	0.00	0.40	0.59	19.08	0.40	0.64	0.44	7.99	24.21	0.00	42.89	0.00	0.00	2.66
Sweet Corn	MR3c	0.55	0.77	1.75	0.24	0.94	1.59	34.26	1.05	1.79	0.32	16.82	19.12	0.00	18.31	0.16	0.73	1.61
Catfish	MR4a	0.00	0.00	2.77	0.00	1.04	0.33	23.37	11.62	1.80	2.60	6.34	25.24	10.67	5.86	0.00	0.22	8.16
Catfish	MR4c	0.00	0.00	4.29	0.00	1.72	0.97	35.38	8.06	2.78	1.81	14.47	18.26	7.41	2.89	0.00	0.53	1.43
Pike	MR5a	0.77	0.18	2.41	0.16	1.23	1.87	28.20	9.04	1.29	1.35	10.84	17.63	4.48	14.81	0.00	0.33	5.42
Pike	MR5c	0.78	0.96	3.96	0.36	1.61	1.32	35.30	5.10	2.14	0.90	17.83	9.09	3.07	13.48	0.37	0.98	2.74
Deer	MR6a	0.09	0.00	1.93	0.21	0.51	0.20	24.28	3.35	1.37	0.68	17.34	43.43	0.00	3.61	0.00	0.10	2.89
Deer	MR6c	0.00	0.00	2.48	0.00	0.82	0.61	36.65	1.15	2.57	0.39	35.92	17.50	0.00	1.40	0.00	0.25	0.26
False solomon's	MR7a	0.77	0.00	1.57	0.00	1.32	3.02	20.68	1.83	1.30	2.89	21.15	22.96	0.00	13.91	1.46	1.70	5.44
False solomon's	MR7c	3.45	2.87	5.06	0.00	2.70	3.19	42.27	1.93	4.35	0.00	22.87	3.68	0.00	3.45	0.93	2.62	0.63
Chokecherry	MR8a	0.12	0.00	0.73	0.26	0.56	1.03	21.97	1.36	2.07	2.33	8.49	40.63	0.00	16.22	0.76	1.37	2.11
Chokecherry	MR8c	2.07	2.16	3.99	0.00	2.02	3.05	39.71	1.55	3.64	0.76	23.65	3.89	0.00	9.32	0.47	1.95	1.78
Fireweed	MR9a	0.30	0.00	1.43	0.26	0.59	1.01	23.52	1.95	1.10	2.36	14.81	24.24	0.00	22.56	1.74	1.74	2.41
Fireweed	MR9c	1.73	1.41	3.65	0.00	1.99	2.42	43.54	1.00	3.60	0.55	26.63	0.11	0.00	10.06	0.91	1.25	1.15
Cattail Root	MR10a	0.60	0.00	0.82	0.00	0.41	0.56	15.33	0.96	1.47	0.93	8.21	22.55	5.23	39.00	0.79	0.00	3.12
Cattail Root	MR10c	2.08	2.73	5.72	0.00	2.47	2.91	33.79	2.88	3.26	0.66	27.24	1.51	0.00	10.71	0.89	1.19	1.97
Corn and Beans	MR11a	results excluded from the analysis																
Corn and Beans	MR11c	results excluded from the analysis																
Bison and Corn	MR12a	0.14	0.07	2.99	0.19	0.61	0.05	19.85	2.15	1.31	0.60	26.55	40.45	0.00	4.36	0.00	0.09	0.58
Bison and Corn	MR12c	0.22	0.08	4.92	0.00	1.04	1.48	33.15	1.14	2.07	0.55	37.58	14.84	1.84	0.72	0.00	0.14	0.22
Bison and Berry	MR13a	0.10	0.00	2.53	0.13	0.54	0.07	18.76	1.73	1.27	0.66	26.15	42.89	0.00	4.57	0.00	0.00	0.59
Bison and berry	MR13c	0.07	0.03	2.51	0.07	0.58	0.22	21.01	1.47	1.55	0.47	34.89	34.37	1.33	1.22	0.00	0.13	0.06
Deer and greens	MR14a	0.00	0.00	1.48	0.13	0.38	0.13	22.94	1.87	1.38	0.62	20.51	43.80	0.00	3.84	0.00	0.14	2.78
Deer and greens	MR14c	0.00	0.00	1.77	0.00	0.51	0.33	30.33	1.64	1.94	0.44	28.74	33.07	0.00	1.08	0.00	0.15	0.00
Berry and Root	MR15a	0.00	0.00	0.15	0.00	0.66	4.52	14.35	0.89	0.55	1.55	24.91	25.49	0.00	21.81	0.00	0.00	5.11
Berry and Root	MR15c	1.55	0.00	4.43	0.00	1.59	5.44	27.37	2.41	2.74	1.16	25.26	8.03	2.33	14.54	0.25	0.35	2.55
Pike and Berry	MR16a	1.30	0.00	2.63	0.00	0.77	2.13	28.05	5.36	1.77	2.25	10.81	23.72	5.03	12.06	0.00	0.48	3.65
Pike and Berry	MR16c	1.58	0.00	4.55	0.00	1.95	2.61	37.10	3.65	2.36	1.41	21.08	7.31	1.97	12.18	0.41	0.00	1.83
Parched dock	MR17a	0.73	0.08	1.11	0.00	0.50	1.05	18.12	1.68	1.06	0.70	16.91	46.19	0.00	10.46	0.00	0.00	1.41
Parched dock	MR17c	1.88	1.82	4.38	0.00	2.59	2.35	38.50	1.89	3.14	0.90	26.34	4.48	0.00	10.11	0.50	0.00	1.13
Beaver	MR18a	0.18	0.00	1.42	0.13	0.26	0.00	22.05	6.87	0.33	0.35	6.33	39.48	2.49	18.48	0.00	0.00	1.64
Beaver	MR18c	0.19	0.00	1.63	0.00	0.38	0.00	33.43	4.66	0.55	0.50	11.29	37.49	2.11	7.28	0.00	0.00	0.51
Bone Marrow	MR19a	0.16	0.00	4.13	0.75	0.98	0.00	28.07	3.31	1.39	0.78	19.13	34.54	4.13	1.90	0.00	0.00	0.74
Bone Marrow	MR19c	0.20	0.00	4.34	0.00	1.09	0.00	31.15	2.69	1.58	0.74	22.17	33.72	0.83	1.32	0.00	0.00	0.16

but the drop was more dramatic in plant samples than in mammals and fish. Saturated fatty acids were least affected by decomposition, so as the unsaturated fatty acids disappeared, the relative percentage of saturated fatty acids in the sample increased dramatically. The presence of C18:3 clearly indicates, however, that after the period of long term decomposition, the residues have not degraded to the level observed in the archaeological residues (see section 8.3).

Although initial levels were high in some cases, only traces of C18:3w3 remained in the experimental cooking residues. In uncooked plant greens, such as false solomon's seal and fireweed, C18:3w3 represents more than 30% of the fatty acid composition. After four days of decomposition, these levels dropped to 5% and 2%, respectively. After long term decomposition, the levels of C18:3w3 were 1% or less. The rate of decomposition of C18:2 was slightly slower. Relatively high levels of C18:2 remained in some cooked samples after four days of decomposition but the amounts steadily declined. After long term decomposition, C18:2 was still present at levels of 10% or more in some cases but this only occurred in samples with very high initial levels of C18:2. The level of C18:2 in uncooked sweet corn is more than 50%; after long term decomposition it represented 18% of the total fatty acids.

Similarly, levels of C18:1s in all samples, except beaver and cow bone marrow, dropped markedly with decomposition. The drop was most dramatic in plant samples, but the rate of C18:1 isomer decomposition was slower than for C18:2 and C18:3. The level of C18:1s in the chokecherry sample dropped from about 50% to less than 4% after long term decomposition. The level of C18:1s in bison fell from more than 40% to 18%; the

level in deer fell from about 33% to 18%. With the sudden loss of polyunsaturated fatty acids, the relative percentage of C18:1s in cooked catfish increased dramatically from about 20% in the uncooked sample to about 35% after 4 days of decomposition; after long term decomposition, it still represented about 25% of the total fatty acids.

The levels of saturated fatty acids were the most stable. Relative increases in percentage composition of virtually all medium (12:0, 14:0 and 15:0) and long chain (16:0 and 18:0) saturated fatty acids can be attributed to the oxidation of polyunsaturated fatty acids. Addition reactions across the double bonds of monounsaturates may also account for some increases in the levels of saturated fatty acids in the samples.

With the loss of very long chain saturated and unsaturated fatty acids, similarities in the composition of the degraded residues increased (Table 9). The fatty acid composition of large herbivore meat and meat cooked with corn was very similar. The level of C16:0 almost matched that of C18:0, each representing 30-40% of the fatty acid composition. The level of C18:1s was about one-half that of C16:0 and C18:0, ranging from 15% to 20%; small amounts of medium chain fatty acids and only traces of C18:2 were detected. Large herbivore meat cooked with plant greens was similar in composition to large herbivore meat cooked with berries and the cow bone marrow sample. These samples had higher levels of C18:1s than meat cooked alone and the C18:0 level was lower, especially in the bone marrow sample. The level of C16:0 was also reduced, representing between 20 and 30% of the fatty acid composition. All experimental residues containing red meat tended to have higher levels of C18:0 and C18:1s and lower levels of C18:2 than either plant or fish residues.

Table 9. Major Fatty Acids in Cooking Residues after Long Term Decomposition

Food	Medium	C16:0	C18:0	C18:1s	C18:2
Large Herbivore Meat	5-10%	30-40%	30-40%	15-20%	~ 2.0%
Lrg. Herb. Meat with Corn	5-10%	30-40%	30-40%	15-20%	~ 1.0%
Lrg. Herb.Meat with Greens	~ 2.0%	~ 30%	~ 30%	30-35%	~ 1.0%
Lrg Herb. Meat with Berries	~ 3.0%	~ 20%	~ 35%	~ 35%	~ 1.0%
Fish - Catfish	5-10%	~ 35%	~ 15%	~ 25%	~ 3.0%
Fish - Pike	5-10%	~ 35%	15-20%	10-15%	10-15%
Pike with Berries	~ 10%	35-40%	~ 20%	~ 10%	10-15%
Seed - Sweet Corn	5-10%	~ 35%	15-20%	~ 20%	15-20%
Berries - Chokecherries	10-15%	~ 40%	20-25%	~5%	~ 10%
Greens - Fireweed	~ 10%	40-45%	25-30%	< 1%	~ 10%
Greens - False solomon's seal	15-20%	~ 40%	~ 20%	3-4%	3-4%
Seed - Dock	10-15%	~ 40%	20-25%	~ 5%	~ 10%
Saskatoon & Prairie Turnip	10-15%	25-30%	~ 25%	5-10%	~ 15%
Root - Cat tail	~ 15%	30-35%	25-30%	1-2%	~ 10%
Medium Mammal - Beaver	~ 3%	30-35%	~ 10%	35-40%	~ 7%
Lrg. Herb. Bone Marrow	~ 5%	~ 30%	20-25%	35%	~ 1%

The fatty acid composition of beaver, a small mammal, was characterized by very high levels of C18:1 isomers, almost 40%. Elevated levels of C18:1s were also found in samples containing bone marrow as well as large herbivore meat cooked with plant greens or berries. The level of C18:0 in the the beaver sample is only about 10%, which is significantly lower than the large herbivore meat with plant or marrow samples. Levels of medium chain fatty acids are very low in the beaver sample, about 2.7%.

The fatty acid composition of boiled pike matched that of pike boiled with berries but both differed somewhat from catfish. Levels of medium chain fatty acids, C16:0 and C18:0 were similar but the level of C18:1s was much higher and that of C18:2 was lower in catfish. Corn differed from the other plant samples in that its levels of C18:1s and C18:2 were much higher; in this respect, its fatty acid composition most closely resembled pike and pike with berries.

The fatty acid composition of all other plant residues shared a high level of commonality. Chokecherry was very similar to fireweed and false solomon's seal except that false solomon's seal had slightly higher levels of medium chain fatty acids; fireweed had slightly higher levels of C18:0 and lower levels of C18:1s and C18:2. The residue from parched dock seeds was practically identical to that of boiled chokecherry. The fatty acid composition of saskatoon and prairie turnip most closely resembled cattail roots, except the level of C16:0 was slightly lower and the levels of C18:1s and C18:2 were higher.

8.3 Archaeological Residues

Ten fatty acids are regularly found in the absorbed residues of the archaeological

vessels examined: C12:0, C14:0, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1w9, C18:1w11 and C18:2. The results of the fatty acid analysis of archaeological sherd residues have been subjected to average linkage hierarchical cluster analysis. The result is the formation of three distinct clusters, each consisting of a number of smaller clusters (Figure 14). The fatty acid composition of samples in cluster C were quite different from the others so the five residues were excluded from the cluster analysis presented in Figure 15 to eliminate possible skewing effects which would make the samples in clusters A and B appear more closely related than they would otherwise. Cluster A is a large relatively tight cluster of residues associated with sites from the grassland, transition zone and parkland. Cluster B is a large but loose cluster of residues from all vegetation zones; almost all residues associated with forest sites appear in this cluster. Cluster C consists of five residues from a forest and a parkland site. The fatty acid composition of the residues associated with each of the minor clusters is presented in Appendix F. Bar graphs of the average fatty acid composition of the minor clusters are given in Appendix G.

Cluster A

Cluster A consists of a total of 132 residues in four major subclusters, I-IV, with eleven minor clusters, A1-A11, which all link together at a RMS distance of 0.89. Three of the major subclusters, I, II and III, representing 129 residues, link at 0.62, indicating they are significantly more closely related to each other than any of them are to subcluster IV. Subcluster I, is the largest subcluster in cluster A. Consisting of five minor clusters, A1 to A5 and one residue, Lake Midden 13, it encompasses a total of 93 residues. Residues from all the grassland, transition zone and parkland sites appear in this

Figure 14. Dendrogram of the hierarchical cluster analysis of archaeological residues.

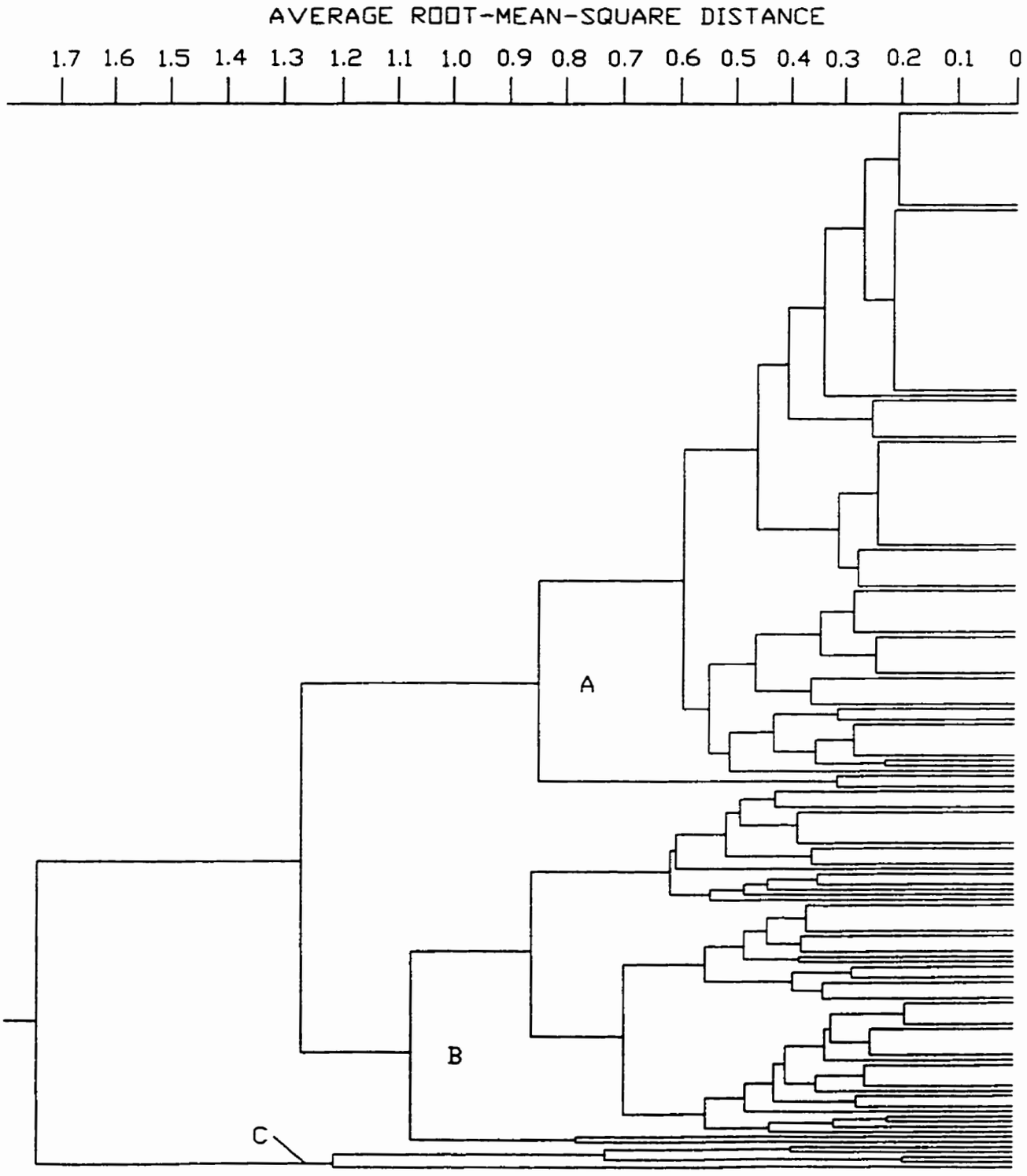
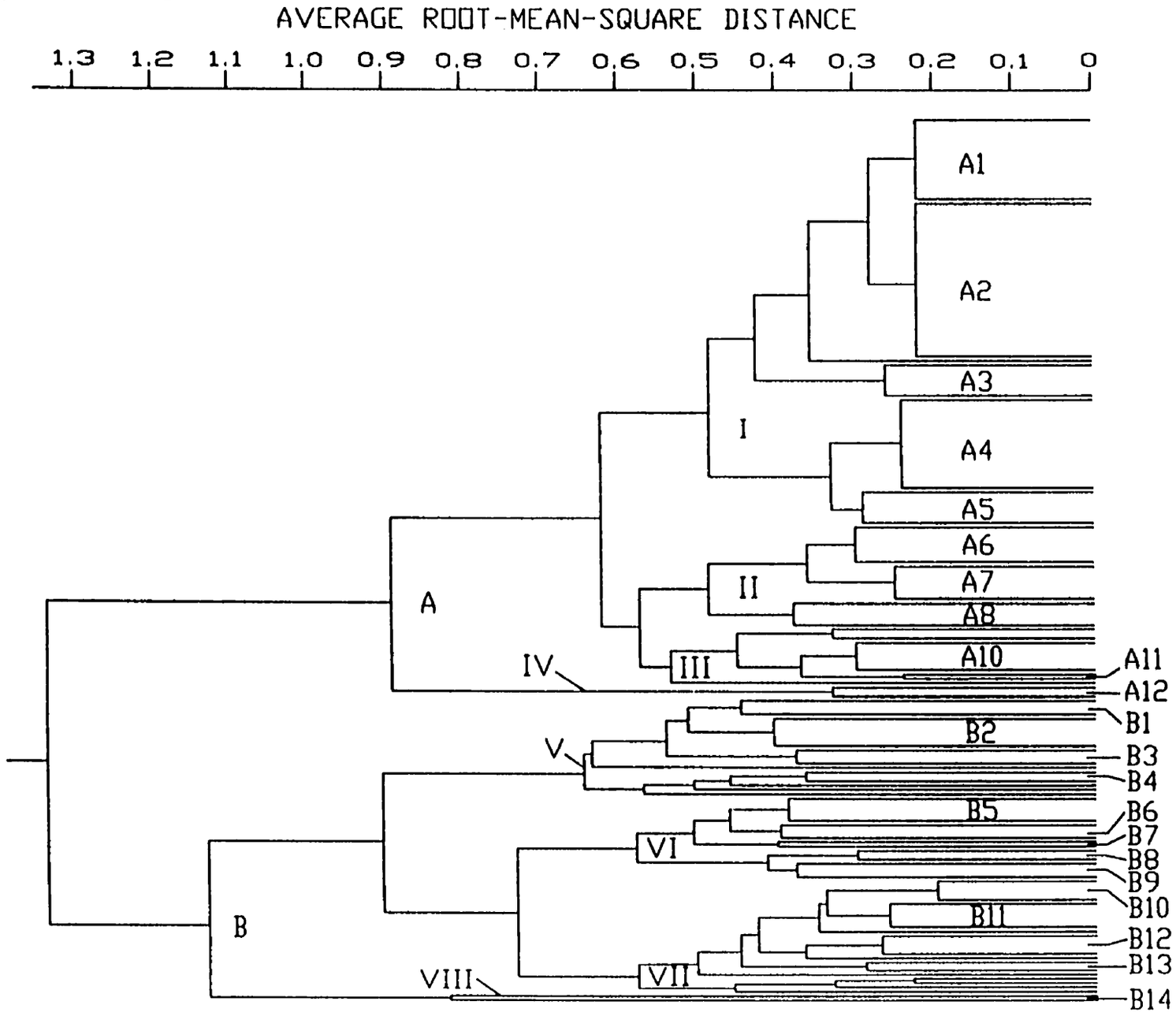


Figure 15. Dendrogram of archaeological residues showing only clusters A and B.



subcluster, which joins at a RMS distance of 0.48. The average fatty acid compositions of the minor clusters are characterized by high levels of both C18:0 and C16:0. Levels of C18:0 are between 37% and 53%; those of C16:0 range from 30% to 46%. Levels of C18:1w9, C17:0 and C14:0 are also significant. The average amount of C18:1w9 ranges from 1% to 9%. Average C17:0 levels are between 3% and 4%; average C14:0 levels are between 3% and 5%. Other fatty acids are present at average levels of less than 2%.

Subcluster II, consisting of three minor clusters, A6 to A8, encompasses a total of 23 sherd residues. Residues from four of the seven grassland, four of the six transition zone and both parkland sites appear in this subcluster, which joins at a RMS distance of 0.49. As above, the average fatty acid compositions of the minor clusters have high levels of both C16:0 and C18:0, but the members of subcluster II also have levels of C18:1w9 in excess of 10%. Levels of C16:0 range from 33% to 38%; those of C18:0 are between 31% and 41%. Average levels of C18:1w9 are from 12% to 15%. Levels of C14:0 and C17:0 range from 3% to 7% and 2% to 3%, respectively. Other fatty acids are present at average levels of less than 2% in clusters A6 and A7. Average levels of C15:0, C16;1 and C18:1w11 are between 2 and 4% in cluster A8.

Subcluster III, consists of three minor clusters, A9 to A11 and one residue, Ross 11, for a total of 13 sherds. Residues from four of the seven grassland sites, together with one transition zone and one parkland site, appear in this subcluster. Clusters A9 to A11 join at a RMS distance of 0.45; Ross 11 links at 0.54. The characterizing feature of subcluster III is the stronger representation of fatty acids other than C16:0 and C18:0. These two continue to dominate the fatty acid composition of the residues; levels of C16:0

range from 27% to 37% and C18:0 levels are between 31% and 42%, but a number of other fatty acids appear at significant levels. Levels of C14:0 run between 7% and 15%. The fatty acids C12:0, C17:0 and C18:1w9 average between 3% and 7%. The Ross 11 residue differs from the other members of subcluster III in terms of its high C15:0 level of 12%; the average amount in the minor clusters A9 to A11 runs between 3% and 4%. Other fatty acids are present at average levels of less than 3%.

Subcluster IV, consists of three residues, Head-Smashed-In 3 and 4 and Sanderson 3, which join at a RMS distance of 0.33. As mentioned, this is the most distinctive subcluster in cluster A, joining the others at a RMS distance of 0.89. The average fatty acid composition of this subcluster is characterized by a very high level of C18:0, 61%. The average level of C16:0 is 24% and C18:1w9 is 7%. Other fatty acids are present at average levels of less than 3%.

To summarize, all the residues appearing in Cluster A are characterized by very high levels of both C18:0 and C16:0. The sum of these two fatty acids usually represents from 70% to more than 80% of the average relative composition. Levels of C18:1w9, C14:0 and C17:0 can be substantial but never more than about 15% of the average relative composition. Many subclusters possess a relatively high level of similarity, linking at RMS distances between 0.28 and 0.37 to form very large groups.

Cluster B

Cluster B encompasses of a total of 69 residues in four major subclusters, V-VIII, with fifteen minor clusters, B1-B15, which all link together at a RMS distance of 1.13. The subclusters are loosely linked compared to cluster A. Significant clusters, consisting

of more than ten residues, do not appear until a RMS distance of 0.35, indicating a relatively lower level of similarity between residues. Three of the major subclusters, V, VI and VII, representing 67 residues, link at 0.90, indicating they are more closely related to each other than any of them are to subcluster VIII.

Subcluster V consists of four minor subclusters, B1 to B4 and four residues, Hartley 9 and 10, Lebret 9 and Sjovold 4. There are a total of 22 residues from two grassland, four transition zone, one parkland and two forest sites; the subcluster joins at a RMS distance of 0.65. This subcluster expresses a rather low level of similarity so it is difficult to generalize the fatty acid composition of its members. Although the average fatty acid compositions of the minor clusters and single residues are varied, levels of C16:0 and C18:1w9 are consistently the highest. Levels of C16:0 range from 22% to 36%; those of C18:1w9 levels range from 14% to 32%. Average levels of C18:0 vary between 5% and 18%. Levels of C14:0 range from 8% to 13%; the average amount of C18:2 varies from 4% to 13%. The amount of C16:1 ranges from 3% to 13%; average levels of C15:0 and C17:0 do not exceed 5%.

Subcluster VI consists of 19 residues in five minor subclusters, B5 to B9. Residues from five of the seven grassland, four of the six transition zone, one parkland and two forest sites appear in this subcluster, which join at a RMS distance of 0.58. The average fatty acid compositions of the minor clusters are characterized by high C16:0 levels, ranging from 36% to 38%. Levels of C14:0 range from 12% to 19% while those of C18:0 vary from 10% to 24%. The average levels of most other fatty acids in the minor clusters, C12:0, C15:0, C16:1, C18:1w9 and C18:2, range between 2% and 13%.

The levels of C17:0 and C18:1w11 are lower, varying from 0 to 3% and 0 to 2%, respectively.

Subcluster VII is the largest subcluster within cluster B, consisting of 26 residues. These sherds are found in five minor clusters, B10 to B14 and five residues, Aschkibokahn 12, 16 and 17 and Cabin Point 8 and 9. Residues from one transition zone, both parkland and two of the three forest sites appear in this subcluster, which links at a RMS distance of 0.58. There is considerable variability in their average fatty acid compositions; however, all of the minor clusters are characterized by very high levels of C16:0, ranging from 41% and 57%. Levels of C18:0 range from 11% to 26%; levels of C18:1 range between 3% and 19%. The average level of C14:0 reaches 11% in minor cluster B13, but is only 3% in the Cabin Point 8 residue. The amount of C18:1w11 ranges from 0 to 8%; C18:2 is found at levels between 1% and 9%. The average level of C17:0 does not exceed 4%; there are lower amounts of C12:0 and C15:0.

Subcluster VIII consists of two sherds, Lake Midden 7 and Bushfield West 16. These two sherd residues share a very low level of similarity, joining at a RMS distance of 0.82. For this reason, their compositions are presented separately. The dominant fatty acids in the Lake Midden residue are C16:0 (28%), C14:0 (20%) and C12:0 (17%). The levels of C15:0, C17:0 and C18:0 are all about 7%. The level of C16:1 is 5%; C18:2 and C18:1w9 each form about 4% of the composition. Traces of C18:1w11 are present. The Bushfield West residue has high levels of C14:0 (29%) and C16:0 (18%). Several other fatty acids are present in significant amounts, including C18:1w9 (14%), C18:0 (11%), C16:1 (10%), C15:0 (8%) and C12:0 (6%). C17:0 and C18:2 occur at levels less than

3%; C18:1w11 is not present. Subcluster VIII joins subclusters V, VI and VII at a RMS distance of 1.13.

In summary, the average fatty acid compositions of the sherds in cluster B are varied but often have high levels of C16:0. This one fatty acid forms between about 30% and 57% of the average fatty acid composition of 61 of the 69 sherds. The residues in the minor cluster B4 (n=6) are an exception to this generalization; the levels of C18:1w9 are slightly higher than C16:0. The residues in subcluster VIII (n=2) have high levels of medium chain fatty acids, accounting for the relatively low level of similarity to the other members of this cluster.

Cluster C

Cluster C consists of 5 residues with compositions which differ significantly from the members of clusters A and B. Four residues in cluster C, Cabin Point 1,3, 4 and 11 are more closely related. The average fatty acid composition of these residues is characterized by high levels of three fatty acids: C18:1w9 (40%), C18:2 (18%) and C16:0 (19%). Levels of C18:0 and C14:0 are 8% and 6%, respectively. Other fatty acids are present at levels less than 4%. When included with the samples in clusters A and B, these four residues cluster at a RMS distance of 0.73. The fifth residue, Bushfield West 18, is not closely related to the Cabin Point samples. It has high levels of C18:1w9 (36%), C18:0 (33%) and C16:0 (25%). Two fatty acids, C12:0 and C18:1w11, could not be detected; the remaining fatty acids each represent less than 3% of the total composition. When included with all other samples, this residue joins the four Cabin Point samples at a RMS distance of 1.21 then cluster C joins clusters A and B at a RMS distance of 1.74.

Principal component analysis strongly supports the groupings produced by the hierarchical cluster analysis. The first three principal components account for 78.44% of the variation in fatty acid composition of the archaeological vessel residues (Table 10). The first principal component has high positive loadings on C12:0, C14:0, C16:1 and C18:2 and high negative loadings on C17:0 and C18:0. The second principal component also has high positive loadings on medium chain fatty acids and high negative loadings on the unsaturated fatty acids, C18:1w9, C18:1w11 and C18:2. The third principal component has a very high loadings on C16:0 and C18:1w11 and a high negative loading on C18:1w9.

Table 10. Principal Components of Archaeological Vessel Residues

Variable	Component I	Component II	Component III
C12:0	0.3349	0.3975	-0.1033
C14:0	0.3524	0.3961	0.0086
C15:0	0.2681	0.4694	0.0078
C16:0	-0.1239	0.0492	0.7153
C16:1	0.3661	0.0041	0.2417
C17:0	-0.3174	0.2985	-0.1404
C18:0	-0.4476	0.0174	-0.1617
C18:1w9	0.2969	-0.3926	-0.3050
C18:1w11	0.2173	-0.3635	0.4448
C18:2	0.3257	-0.2943	-0.2870
%Variability	44.27%	19.21%	14.96%
Eigenvalue	4.4287	1.9215	1.496

Separate plots of the first principal component against the second are presented for residues from each vegetation zones to enhance the clarity by reducing the degree of overlap. The plot of principal components scores of grassland vessel residues show a strong cluster of 55 samples between PRIN1 values of -2.5 and -0.5 and PRIN2 values between -1 and 1 (Figure 16). This grouping corresponds to cluster A produced by the hierarchical cluster analysis. The PRIN1 values of the 21 remaining grassland residues are higher, up to about 4.3; the PRIN2 values of the other samples reach as high as 4 but they rarely fall below 0. The plot of principal components scores from the transition zone vessel residues also show a concentration of samples in the same area; 42 of the residues fall within the cluster (Figure 17). The other 27 transition zone residues fall outside the cluster and are more widely distributed than the grassland residues. The PRIN1 values of these are higher, a few approaching 5; the PRIN2 values range from about -2 to 6.

The distribution of parkland residues in the scatterplot is very similar to the transition zone residues (Figure 18). About one-half of the parkland residues fall in the area of the cluster. The highest PRIN1 value is 5; this sample also has the highest PRIN2 value, about 3.5. The lowest PRIN2 value among the parkland residues is -2. The scatterplot of principal component scores of the forest residues is quite distinct (Figure 19). Only two of the samples fall within the range of the cluster; the majority of forest samples have higher PRIN1 values and lower PRIN2 values. The PRIN1 values of the forest samples ranges from about -1 to almost 5. The forest residues produced a very wide range of PRIN2 values, from -5 to more than 4.

Figure 16. Plot of PRIN1 versus PRIN2 scores for archaeological residues from grassland sites.

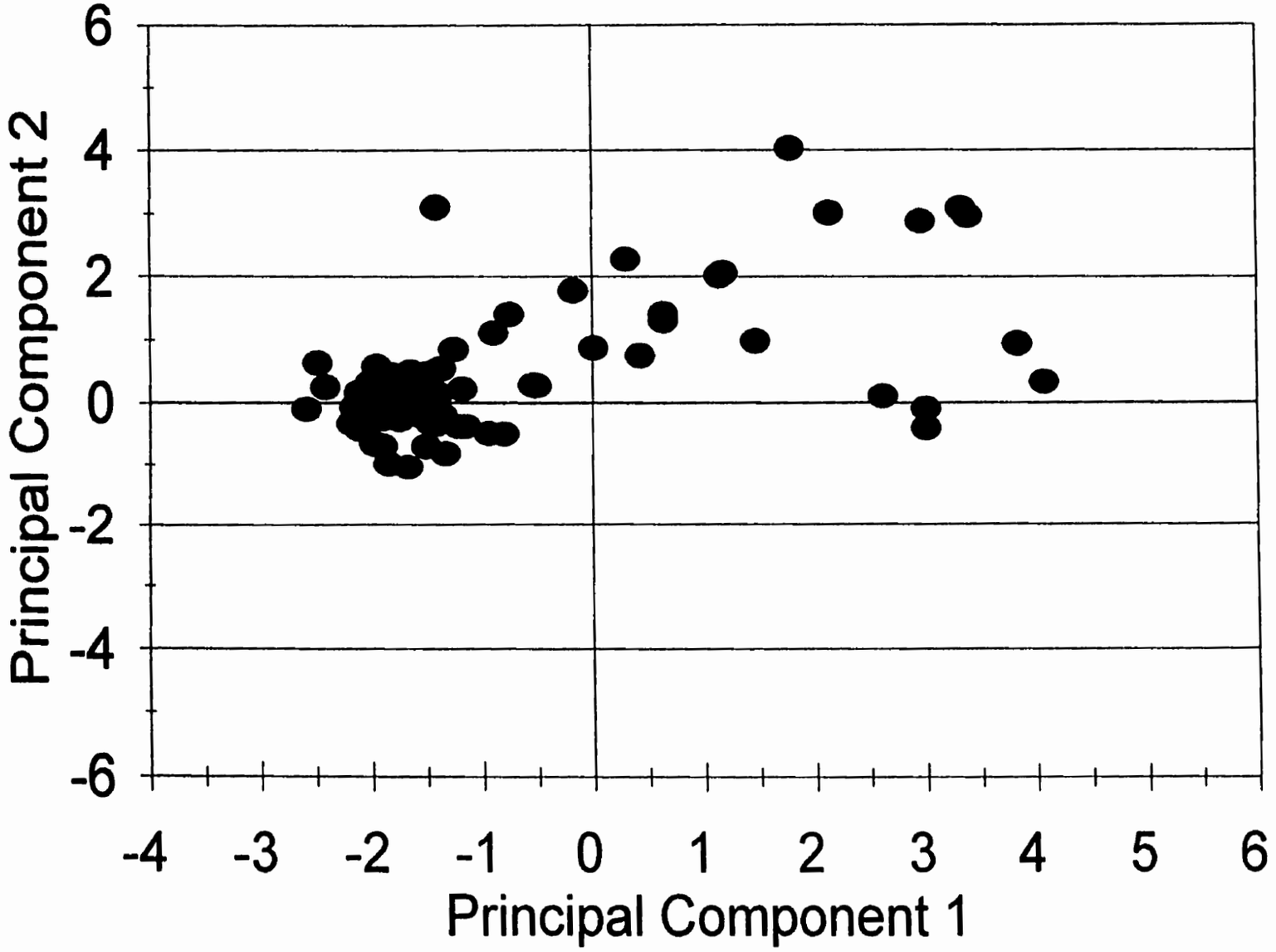


Figure 17. Plot of PRIN1 versus PRIN2 scores for archaeological residues from transition zone sites.

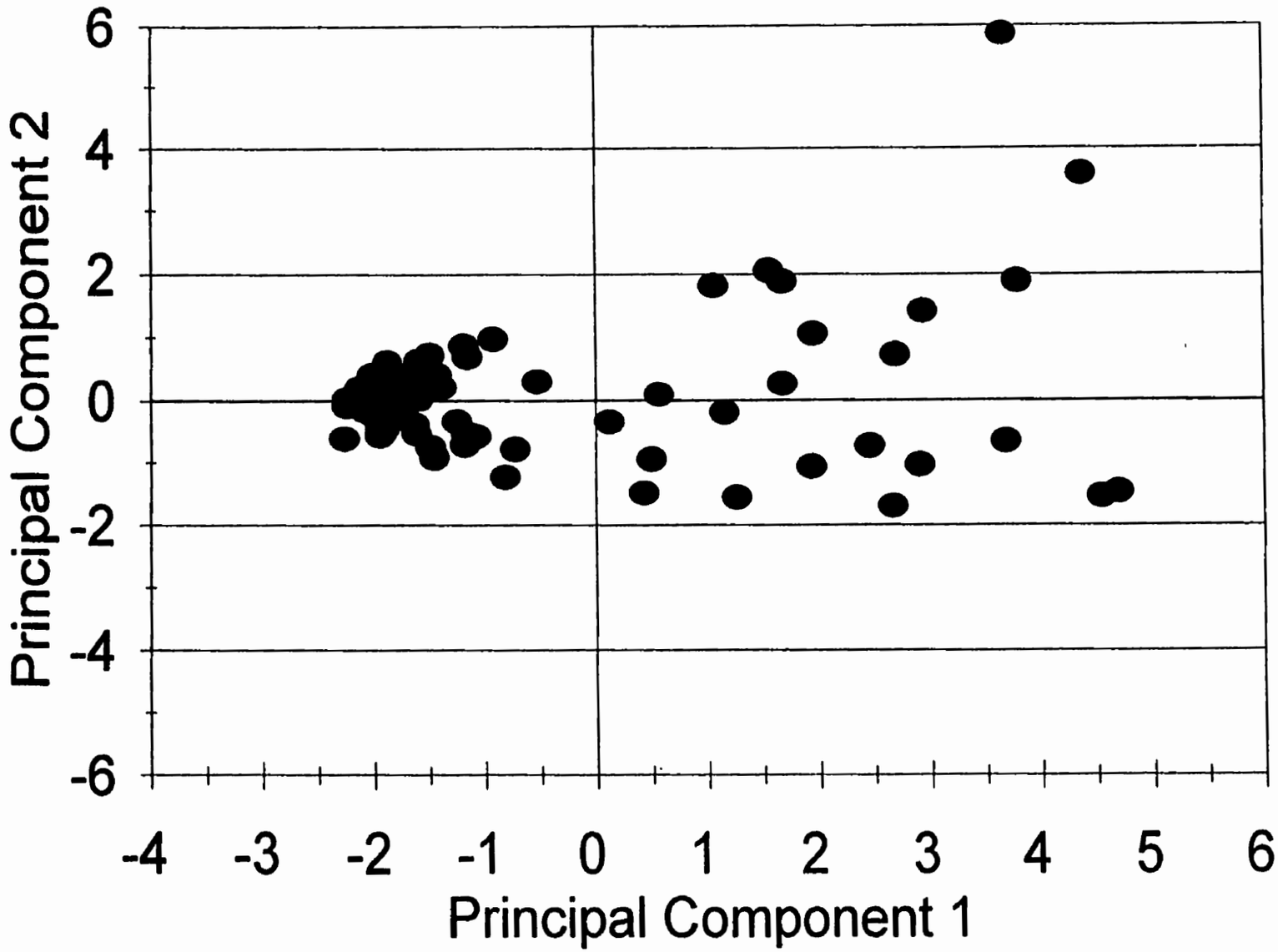


Figure 18. Plot of PRIN1 versus PRIN2 scores for archaeological residues from parkland sites.

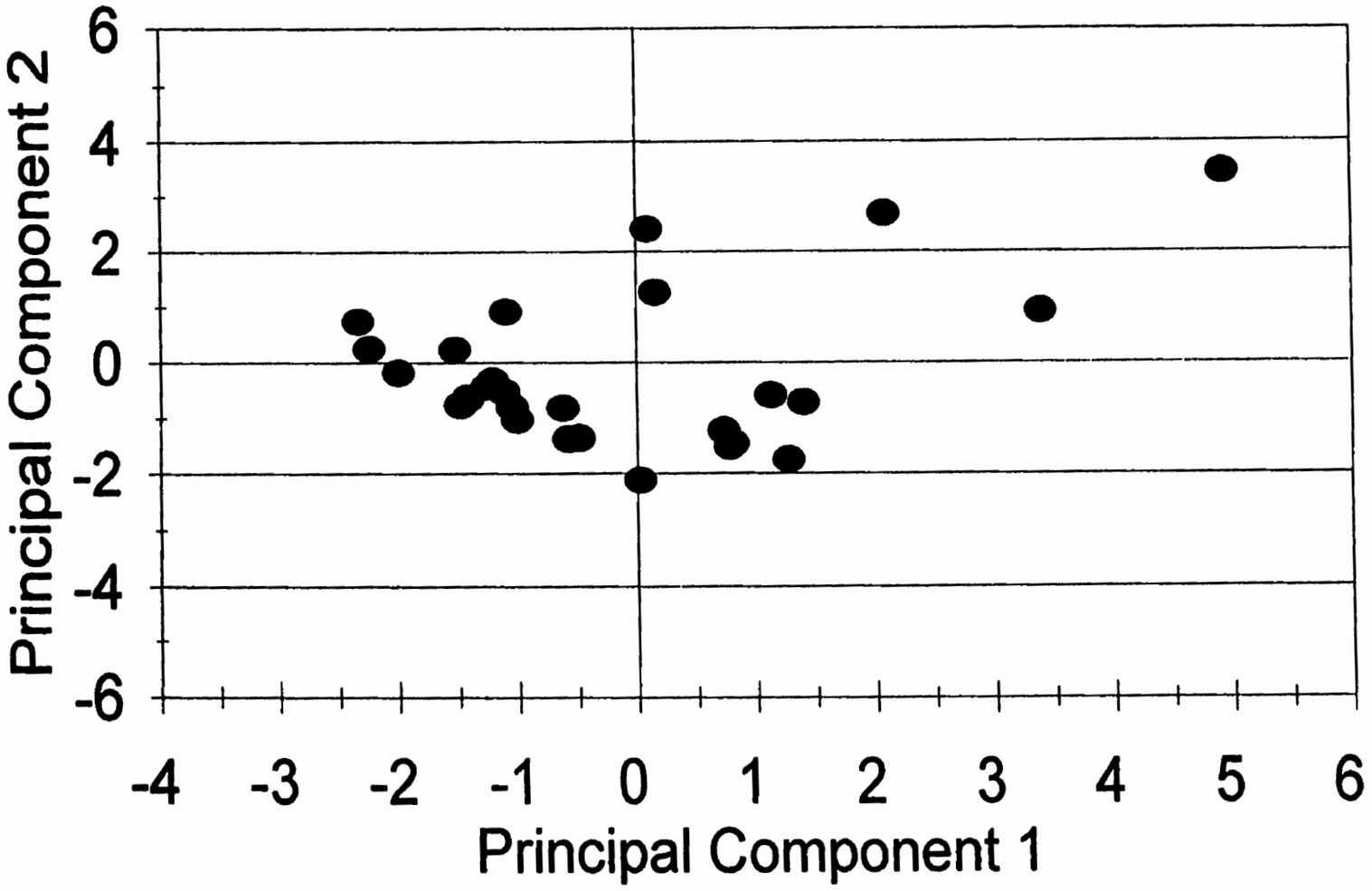
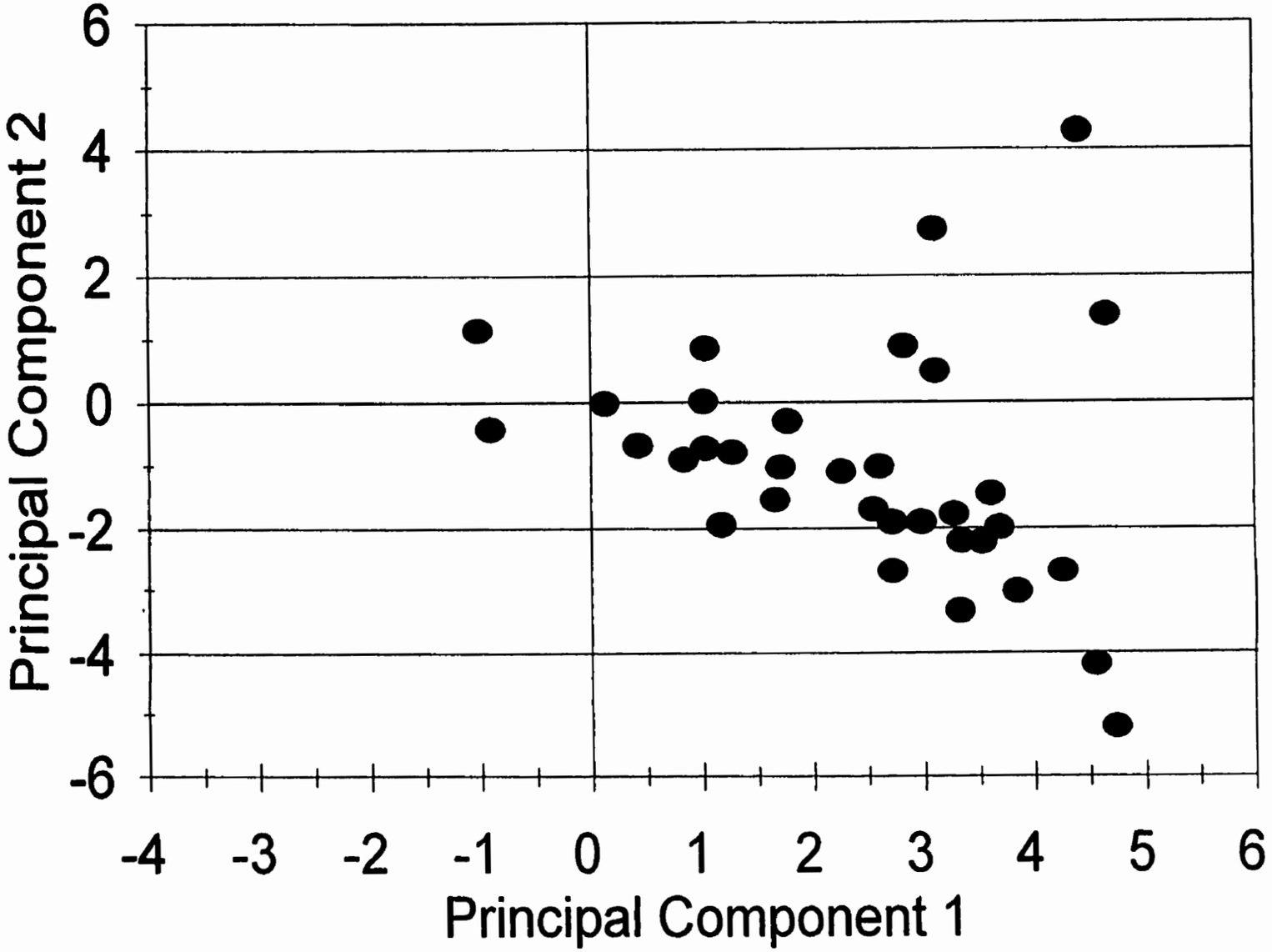


Figure 19. Plot of PRIN1 versus PRIN2 scores for archaeological residues from forest sites.



The principal components show that the strong grouping of grassland, transition zone and some parkland residues identified through the hierarchical cluster analysis is real. The loose cluster of primarily forest, parkland and transition zone sherds produced by the cluster analysis apparently represents all residues that fall outside of the tight grouping. The wide range in values of PRIN1 and PRIN2 reflect the high level of variability in residue compositions.

8.4 Summary

Hierarchical cluster and principal component analyses are statistical methods designed to quickly and objectively process a large number of samples, each described by several variables. Using these techniques, clustering in the fatty acid composition of modern reference samples are apparent. Large mammals, fish, and plant samples form discrete clusters. Different sections of the plants, such as roots, greens, berries and seeds form minor clusters. The fatty acid composition of deer fat, squirrel, grouse and cattail seeds are so distinct they do not readily cluster with any group.

Cooking and decomposition results in the rapid loss of almost all very long chain and polyunsaturated fatty acids. Monounsaturated fatty acids of chain lengths up to 18 carbons are relatively more resilient but saturated fatty acids are by far the most stable. After a long period of decomposition, levels of either C16:0 and C18:0 or C18:0 and C18:1 remain very high in the experimental cooking residues containing red meat. After a long period of decomposition, only the level of C16:0 remains high in fish samples but moderate levels of either C18:1 or C18:1 and C18:2 are present. The loss of very long chain and unsaturated fatty acids reduces much of the variation between plant samples.

The cooking residues of plants tend to have high levels of C16:0, a moderate level of C18:0 as well as significant amounts of both medium chain fatty acids and C18:2.

Both hierarchical cluster and principal component analyses identify a strong similarity in the fatty acid composition of grassland vessel residues and most transition zone vessel residues. About one-half of the sherds from parkland sites also share these traits. The fatty acid composition of all of these samples, which appear in cluster A, is high in both C16:0 and C18:0. The fatty acid composition of the sherds that do not fall within this cluster is highly variable.

Chapter 9 - Interpretations

9.1 Identifying Archaeological Vessel Residues

As shown in the previous chapter, fatty acids, in particular unsaturated fatty acids, tend to degrade over time, so the fatty acid composition of an archaeological vessel residue is different from its material of origin. Researchers have proposed different methods of relating the fatty acid composition of the decomposed residue to that of unaltered specimens. One method employs a ratio of fatty acids which appears not be altered by oxidation. Patrick *et al.* (1985) used the ratio of the C18:1 fatty acid isomers, oleic and vaccenic, to identify the residue on South African pottery as seal.

Two other methods use ratios which separate different modern food classes. Marchbanks (1989) used the relative percentage of two saturated fats in a sample (%S) to characterize them. The amount of two saturated acids, lauric (C12:0) acid and myristic (C14:0) acid, was divided by the sum of the amount of saturated fatty acids and unsaturated linoleic (C18:2) and linolenic (C18:3) present in the residue (Marchbanks 1989:68). The %S values for modern plants, fish and land animals clearly separated these samples (Marchbanks 1989:97).

Skibo (1992:89-97) characterized the fatty acids in his sample of modern Kalinga rice and meat/vegetable cooking vessels by calculating ratios of the most common fatty acids, C16:0, C18:0 to C18:1. All of the modern food samples could be discriminated using the ratios of C18:0/C16:0 and C18:1/C16:0 (Skibo 1992:93-97). The effectiveness of these ratios did not extend to the residues of modern vessels used to cook more than one food item or to archaeological samples.

Another technique involves visually comparing the cumulative percentages of fatty acids normalized to 100%. Morgan *et al.* (1983) used this method to show that the mean composition of the residue found in a Thule midden resembled the average composition of seals more closely than the average composition of whales. Deal *et al.* (1991) used a similar method to characterize vessels residues from two sites in New Brunswick. The cumulative percentages of the fatty acid composition of their residues were compared to those of 13 Precontact residues tentatively identified in the literature.

In this study, the fatty acid compositions of experimental cooking residues are used to characterize the residues. The level of decomposition is higher in the archaeological residues so direct comparison with experimental residues, even after long term decomposition, is not possible; however, the characteristics of the decomposed experimental cooking residues serve as a guide for the identification of archaeological residues. The experiments indicate that cooking foods with high levels of unsaturated fatty acids results in rapid and significant changes in their fatty acid composition. The results also indicate that it is not possible to distinguish plant roots, greens, berries or seeds by their thermal and oxidative decomposition products. The composition of foods high in saturated fatty acids is least affected by these decomposition processes. Although the experimental residues are not fully decomposed, trends observed over the four-day and long-term periods indicate the direction of future alterations. In particular, the levels of the polyunsaturated fatty acids, C18:3 and C18:2, and monounsaturated fatty acids, C14:1, C15:1, C16:1, C17:1, and the two C18:1 isomers, in the samples will decrease and the relative percentages of the saturated fatty acids will increase.

The fatty acid compositions of the experimental residues originating from boiling the meat of two large herbivores, bison and deer, are very similar. After long term decomposition, both have very high levels of C16:0 and C18:0, between 30 and 40%, with combined levels of the two C18:1 isomers ranging from 15% to 20%. There are low levels of medium chain fatty acids and C18:2, as well. Adding sweet corn to the meat does not greatly change the fatty acid composition of the resulting residues. With the addition of berries or plant greens, however, the level of C18:1s increase to over 30%, which is equal to or higher than C18:0, and there is a decrease in the amount of C16:0. The fatty acid composition of boiled cow bone marrow is virtually identical to that of large herbivore boiled with berries or plant greens. The level of C18:0 in fresh bone marrow is low but apparently increases in cooked samples through the decomposition of C18:1s to C18:0. This data shows that high levels of C18:0 are a characteristic of the cooking residues of large herbivore products. High levels of C18:0 together with higher levels of C18:1s are a characteristic of both boiled bone marrow and large herbivore meat cooked with plant material (berries or greens); evidence of corn may not be detectable.

The fatty acid composition of the boiled beaver sample is similar to the large herbivore samples in terms of the C16:0 level but differs from large herbivores in that the level of C18:0 is very low and the level of C18:1 isomers is extremely high. Cooking experiments involving other types of small mammals must be conducted to determine if this pattern is characteristic. Fresh muskrat meat differed from fresh beaver in terms of its higher C18:2 level and the level of C18:1s was lower. With cooking and over time, however, the deterioration of C18:2 may result in a sharp increase in C18:1s. If this

change occurred, the cooking residue of muskrat would resemble that of beaver, although the C18:2 level may be higher.

For cooking residues of fish, boiled with or without berries, the level of C16:0 is similar to large herbivores, but, like beaver, the amount of C18:0 is significantly lower. The levels of C16:0 range from about 35% to 40%; C18:0 runs from 15% to 20% and the C18:1s vary from about 10 to 25%. Levels of C18:2 are higher in fish residue, but there is significant variation between fish species. The fatty acid composition of sweet corn is very similar to that of pike, but pike boiled with berries has higher levels of medium chain fatty acids. Further decomposition of unsaturated fatty acids may increase the relative level of saturates, but levels of C18:0 less than 25% can be used as method of distinguishing fish and sweet corn from large herbivore meat. High levels of medium chain fatty acids may provide a way of discriminating fish or sweet corn boiled with plants from fish or sweet corn alone. It is important to note, however, the fatty acid composition of sweet corn is quite similar to other varieties of seeds and berries. As shown in section 8.1, subcluster VII, generated by hierarchical cluster analysis, contains a tight cluster of sweet and flint corn, sunflower, squash, bulrush, saskatoon and hawthorn with pincherry forming a looser linkage. Further experimentation is required to determine if the fatty acids profiles of all these foods will resemble fish after oxidation and thermal decomposition.

The residues of boiled greens, berries and roots differ from those of meat, fish and sweet corn in that the levels of C18:1s are very low and the sum of medium chain fatty acids exceeds 10%. These are the major characteristics of plant cooking residues. The level of C16:0 varies widely but is often higher than 30% and the level of C18:0 in plants

is between that of meat and fish, ranging from 20 to 30%. The level of C18:2 is quite high so the relative amount of saturates would increase with further decomposition of this polyunsaturated fatty acid. If the fatty acid composition resembles the experimental cooking residues of plants, except that the value of C18:0 is higher, this may indicate the presence of large herbivore.

The general characteristics of the experimental and modern residues provide a useful guide for identifying the material of origin for the archaeological residues, but it is still necessary to predict changes in fatty acid composition resulting from longer periods of decomposition. Further experimentation will undoubtedly lead to refinements in setting the actual points of divisions between the different categories. The criteria used to identify the archaeological vessel residues in this study are presented below.

If the total fatty acid composition of the archaeological vessel residue is such that:

1) the sum of medium chain fatty acids ≤ 15%, C18:0 ≥ 27.5% and C18:1s ≤ 15% then it is probably of LARGE HERBIVORE origin.

2) C18:0 ≥ 25% and 15% ≤ C18:1s ≤ 25% then it is probably of LARGE HERBIVORE WITH PLANT or BONE MARROW origin.

3) C18:0 ≥ 25% and the sum of medium chain fatty acids ≥ 15% then it is probably of PLANT WITH LARGE HERBIVORE origin. The level of C18:2 tend to be higher in these residues.

4) C18:1s ≥ 25% with C18:0 low then it is probably of BEAVER origin. Levels of C18:2 may be higher in the samples.

5) C18:0 ≤ 25%, 15%≤ C18:1s≤ 27.5% and the sum of medium chain fatty acids is ≤ 15% then it is probably of FISH or CORN origin.

6) C18:0 ≤ 25%, 15%≤ C18:1s≤ 27.5% and the sum of medium chain fatty acids is greater than 15%, then it is probably of FISH or CORN with PLANT origin.

7) C18:0 ≤ 27.5%, C18:1s ≤ 15% and the sum of medium chain fatty acids ≥ 10% then it is probably of PLANT origin.

The identifications of the archaeological residues are presented in Appendix H.

9.2 Comparisons of Residue Identifications and Hierarchial Clustering Analysis

The validity of these criteria is supported by comparisons of these identifications to the results of the statistical analyses of the archaeological residues. The hierarchical cluster analysis divided the archaeological vessel residues into three main groups, A, B and C. Most of the 132 members of cluster A were closely related as indicated by large size of the subclusters and the short RMS distances at which they linked. In contrast, the 69 members of cluster B were not very similar; its subclusters were very small and joined at long RMS distances. Four of the five members of cluster C were fairly similar, one was quite different. Identifications of archaeological residues within each of the minor clusters are presented in Table 11; the identifications of individual residues which fell outside minor clusters are presented in Table 12. A summary of the these results are presented with the dendrogram for archaeological residues within the major clusters in Figure 20.

Strong correlations exist between the composition of the clusters and the identifications of residues within them. The residues in cluster A were identified as large herbivore alone or in combination with plant. All residues within subcluster I, which includes minor clusters A1-A5 and Lake Midden 13, were identified as large herbivore. Identifications of residues within subcluster II, which consists of minor clusters A6-A8, were divided between large herbivore, n=12, and large herbivore with plant or marrow, n=11. Subcluster III includes the minor clusters A9 - A11 and Ross 11. Five of these

Table 11. Identified residues within minor clusters generated by cluster analysis.

Cluster	Large Herb.	Lg Herb. & Plant or Marrow	Plant & Lg Herb.	Plant	Fish & Plant	Fish	Beaver
I:A1	19						
I:A2	36						
I:A3	8						
I:A4	21						
I:A5	8						
II:A6	6	3					
II:A7	3	5					
II:A8	3	3					
III:A9	3						
III:A10	2		5				
III:A11			2				
IV:A12	3						
V:B1					3	1	
V:B2					3	4	
V:B3					2	2	
V:B4							3
VI:B5				6			
VI:B6				4			
VI:B7				2			
VI:B8				3			
VI:B9			2	2			
VII:B10						5	
VII:B11				1	1	4	
VII:B12						5	
VII:B13				3			
VII:B14				2			
VIII:B15				2			
IX:C1							4

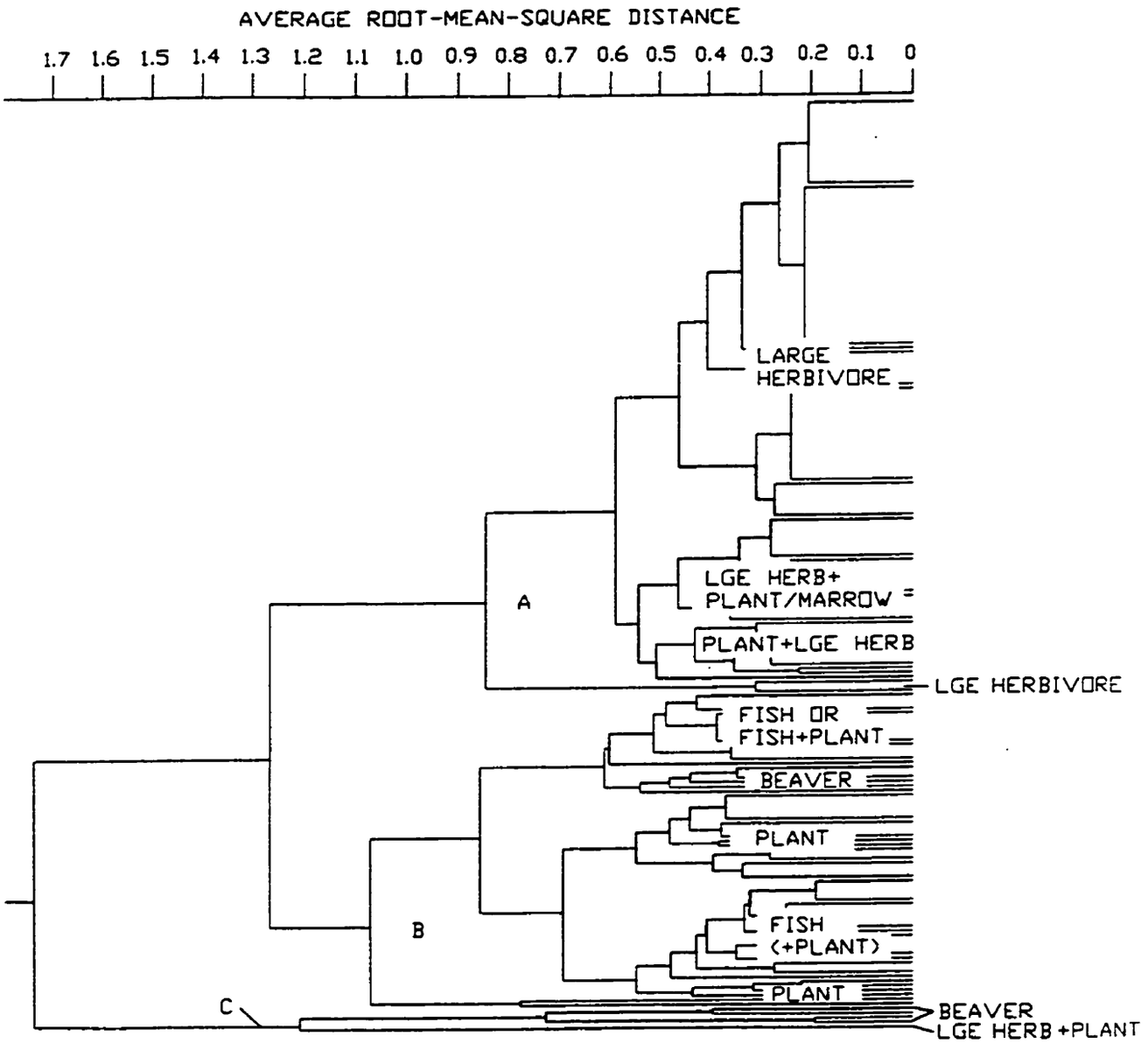
Table 12. Identified residues within subclusters generated by cluster analysis

Cluster	Large Herb.	Lg Herb. & Plant or Marrow	Plant & Lg Herb.	Plant	Fish & Plant	Fish	Beaver
I:LkMid13	1						
III:Ross11			1				
V:Hartley10					1		
V:Hartley9							1
V:Lebret9							1
V:Sjovold4							1
VII:Asch12				1			
VII:Asch17						1	
VII:Asch16						1	
VII:CabPt9	1						
VII:CabPt8	1						
IX:Bush18		1					

residues were identified as large herbivore and seven appear to be plant with large herbivore. The residues in subcluster IV were identified as large herbivore.

Most residues in cluster B were identified as either plant, fish or corn, or, fish or corn with plant. Six were identified as beaver and two were identified as plant with large herbivore. Subcluster V, which is rather loosely linked, includes the minor clusters B1-B4 and four residues, Hartley 10, Hartley 9, Lebret 9 and Sjovold 4. The residues within minor clusters B1, B2 and B3 as well as Hartley 10, which is linked to them, are identified as fish and plant, n=9, and fish alone, n=7. The three residues in minor cluster B4 and the samples which link to it, Hartley 9, Lebret 9 and Sjovold 4, most closely resemble beaver. Subcluster VI includes five minor clusters B5-B9. All 15 residues in B5, B6, B7 and B8 were identified as plant. Two residues in B9 were identified as plant; the other two were

Figure 20. Dendrogram of the hierarchical cluster analysis of archaeological residues with subclusters identified.



identified as plant with large herbivore. Subcluster VII includes the minor clusters B10-B14 and five residues, Aschkibokahn 12, 16 and 17 and Cabin Point 8 and 9. The residues in minor clusters B10 and B12 as well as Aschkibokahn 16 and 17, were identified as fish. The residues in minor clusters B13 and B14 and Aschkibokahn 12 are likely plant. Four of the residues in minor cluster B11 were identified as fish, one appears to be plant, and another is classed as fish and plant. Both Cabin Point 8 and 9 were identified as large herbivore, but there were extremely high levels of C16:0 in these samples. The two residues in subcluster VIII are considered to be plant.

Cluster C consists of four residues in a minor cluster C1, all of which were identified as beaver. The fatty acid profile of the other residue, Bushfield West 18, almost perfectly matches that of the experimental residue of marrow or large herbivore cooked with either greens or berries after long term decomposition.

The samples identified as beaver in cluster C differ slightly from those in cluster V:B4 and the three residues that link to them. All samples are high in C18:1s and C18:2 and low in C18:0, which identifies them as beaver, but the slightly higher levels of C16:0 and C18:0 in the latter samples may have caused them to be included in cluster B, rather than cluster C. The average C16:0 value of the cluster B residues identified as beaver is close to 25% but it is 20% for the cluster C residues. The cluster B residues have an average C18:0 value of about 12% while it is 8% for the cluster C residues. The level of one of the C18:1 isomers, C18:1w11, is generally higher in the cluster B residues.

The categorization of the archaeological vessel residues, based on the fatty acid composition of degraded experimental cooking residues, corresponds well with the

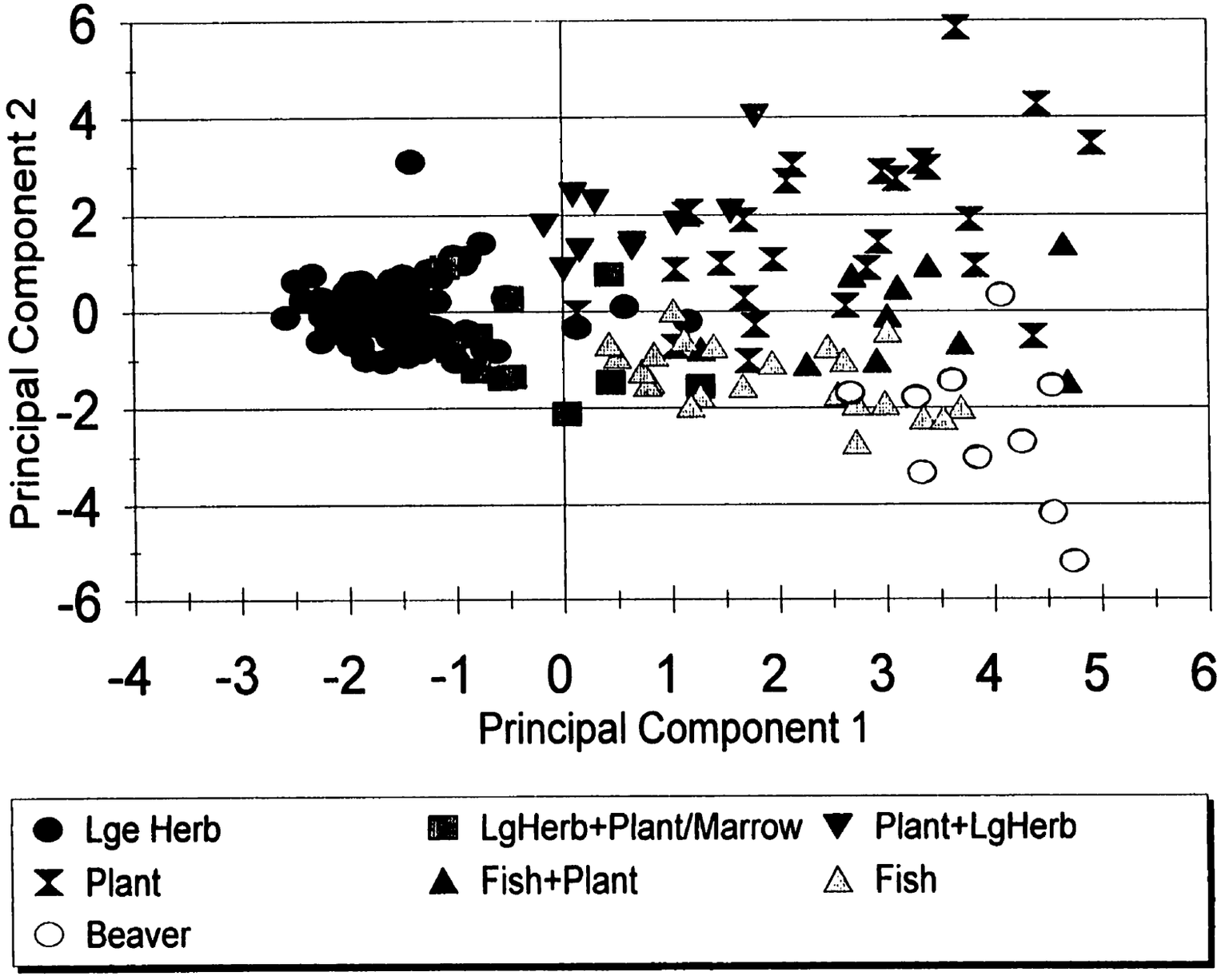
groupings generated by hierarchical cluster component analysis. The level of similarity between samples, as reflected in the normalized RMS distances, is strongest among the residues identified as large herbivore. Minor clusters consisting of residues identified as plant occur, as do minor clusters consisting of residues which resemble beaver. Residues identified as fish or fish with plant often appear in the same cluster.

9.3 Comparisons of Residue Identifications and Principal Component Analysis

Comparisons of the identified residues with the results of principal component analysis also provide support for the classification criteria. As mentioned previously, archaeological residues were identified on the basis of the fatty acid compositions of the experimental cooking residues after long term decomposition. Plotting these identifications against their first and second principal component scores results in the formation of groupings which correspond to the proposed residue classifications. This is clearly shown when the principal component scores of all identified residues are plotted together in Figure 21.

The categorization of the archaeological vessel residues, based on the fatty acid composition of the degraded experimental cooking residues, corresponds with the groupings generated by principal component analysis. Virtually all archaeological vessel residues identified as large herbivore appear in the strong cluster of samples between PRIN1 values of -2.5 and -0.5 and PRIN2 values of -0.5 and 0.5. A group of residues identified as plant form a loose cluster in the upper right section of the scatterplot. These residues have PRIN1 valuse betweeen 1 and 5 and PRIN2 values between -1 and 6. Samples identified as large herbivore with plant or marrow appear to the right of the major

Figure 21. Plot of PRIN1 versus PRIN2 scores for all identified archaeological residues.



cluster, adjacent to samples believed to originate from plants with traces of large herbivore. As expected, the relative amount of either plant or large herbivore product in each residue is reflected in its proximity to one or the other group. A cluster of residues identified as fish is apparent; similarly, samples believed to contain both fish and plant are found between the fish and the plant groupings. Samples which most closely resemble beaver also form a loose cluster. These samples have high PRIN1 values, between 2.5 and 5, and low PRIN2 values, between -6 and 1. When the distribution of the identified residues is examined with respect to vegetation zone, the similarities and differences become clearer.

In order to reduce the degree of overlap, separate scatterplots of the first principal component score, PRIN1, against the second principal component score, PRIN2, for identified residues from each vegetation zones are also presented. The distribution of identified residues from grassland sites is striking (Figure 22). Of the 76 residues from grassland sites, 55 were identified as large herbivore and appear in the tight cluster. Several residues (n=15) were identified as plant or plant with traces of large herbivore. Only three residues appear to represent large herbivore and plant or marrow. One vessel residue was identified as fish, one appears to represent fish with plant and another beaver.

The scatterplot of identified residues from transition zone sites is presented in Figure 23. Residues identified as large herbivore form the majority. Most of the transition zone residues identified as large herbivore appear within the limits of the cluster observed in the grassland samples; however, three samples with positive PRIN1 values do not. Lebret 4, Stott 4 and Hartley 7 have higher levels of medium chain fatty acids, C16:1

Figure 22. Plot of PRIN1 versus PRIN2 scores for identified residues from grassland sites.

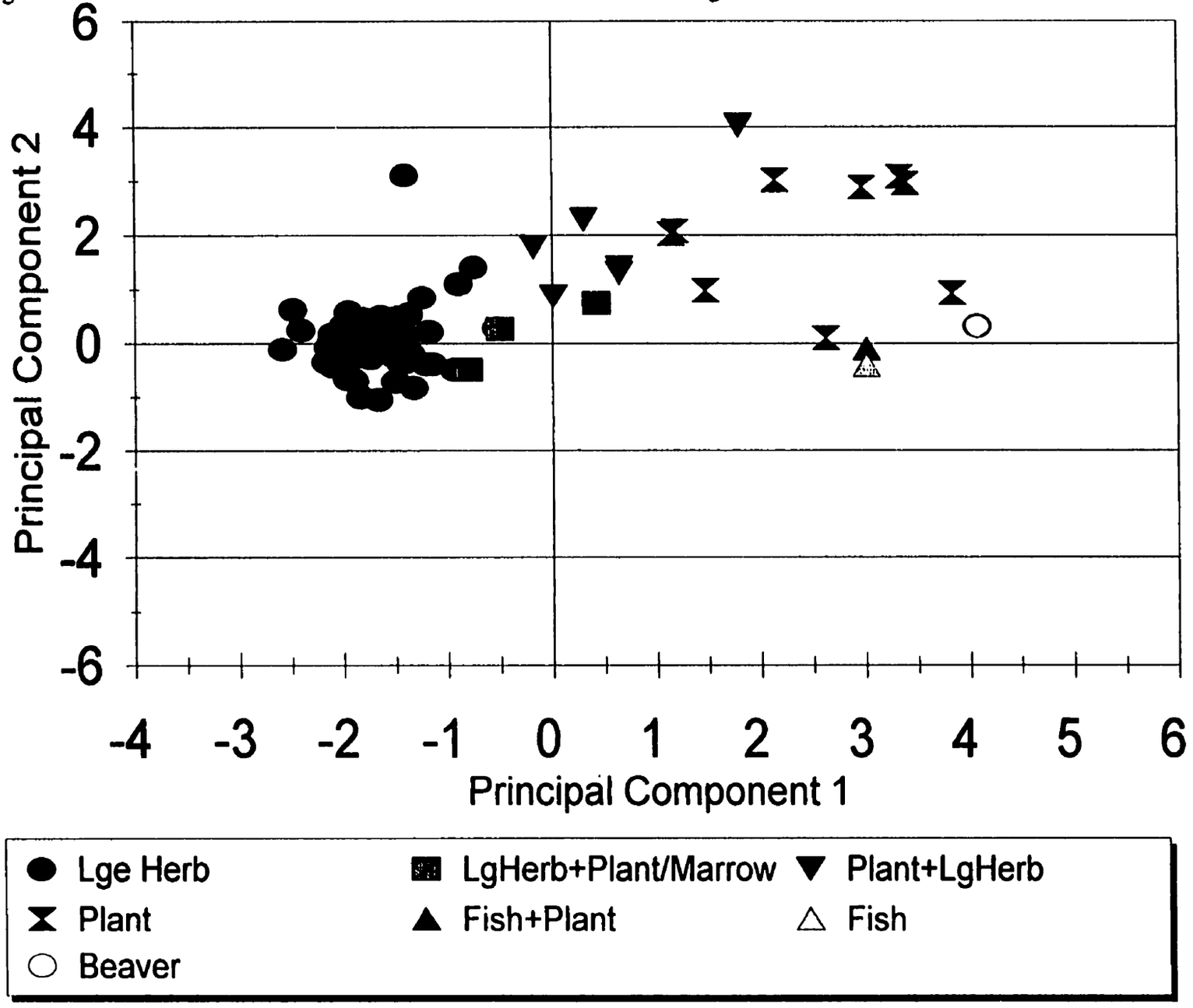
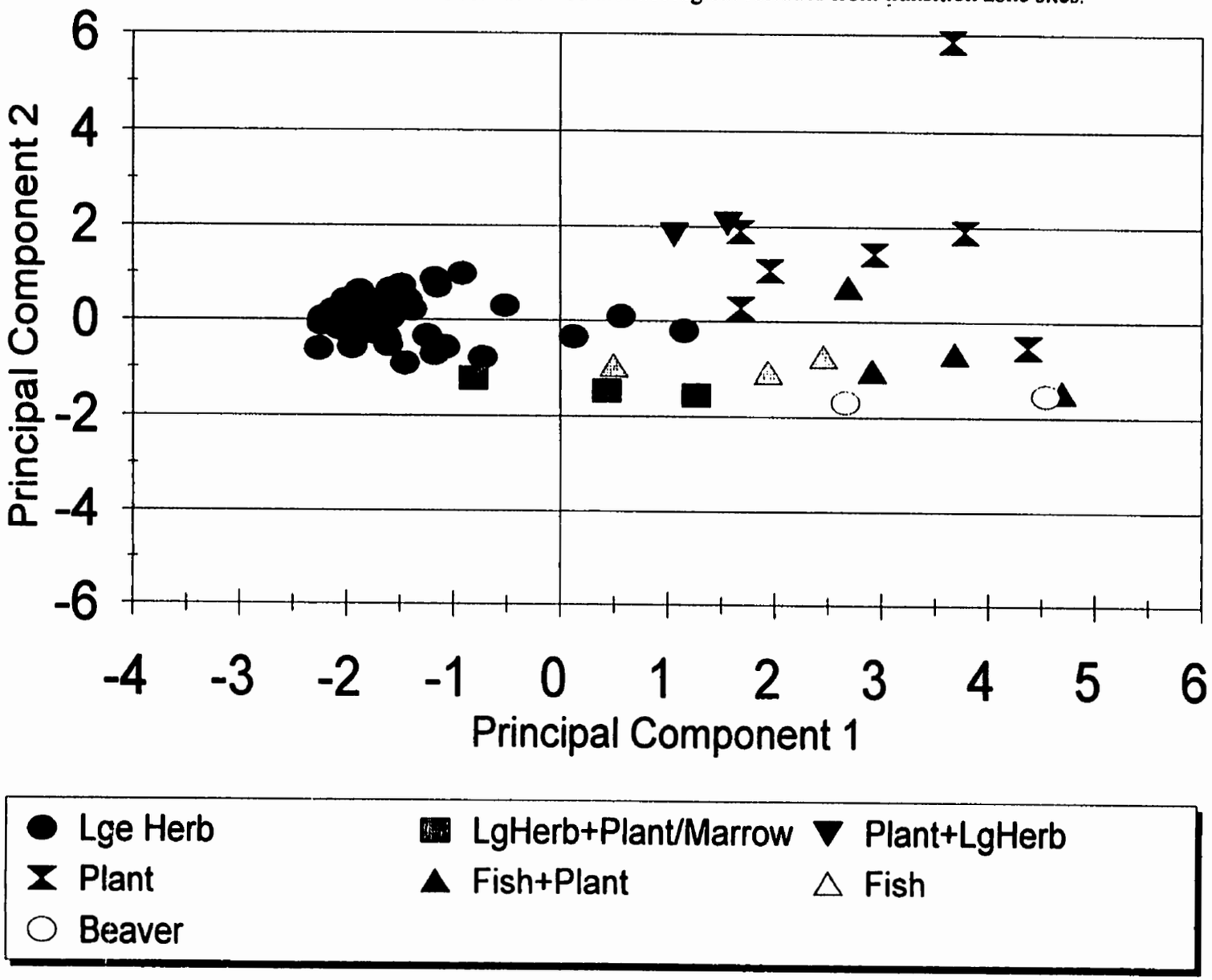


Figure 23. Plot of PRIN1 versus PRIN2 scores for identified archaeological residues from transition zone sites.



and/or C18:2 than most samples identified as large herbivore. Since the first principal component has relatively high positive component loadings on these fatty acids (Table 10), these samples fall to the right of the large herbivore cluster. In the Hartley 7 and Stott 4 residues, the sum of the medium chain fatty acids is 13.6% and 12.4%, respectively, which suggests that traces of plant material elevated the levels of these fatty acids. The high level of C18:1s in the Lebret 4 residue, 12.5%, may also suggest traces of plant material. Seven residues from transition zone sites were identified as plant. A few residues identified as fish or corn with plant, fish or corn, large herbivore and plant or marrow, plant with traces of large herbivore and beaver were present.

The distribution of identified residues from parkland sites is presented in Figure 24. Many of the residues were identified as either large herbivore or large herbivore with plant or marrow. Six residues, identified as fish, form a tight cluster. Other identified residues include plant, plant with large herbivore and fish and plant.

The distribution of identified residues from forest sites is quite different from the other vegetation zones (Figure 25). Most of the forest samples were identified as fish or plant. Several forest residues are identified as beaver and a few were fish and plant. Evidence of large herbivores was detected in only two residues.

9.4 The Distribution of Identified Residues Between Vegetation Zones and Sites

The results of the residue analysis show that differences in the relative occurrence of identified vessel residues exists between vegetation zones. A summary of the residue identifications for each vegetation zone is presented in Table 13. Similar numbers of residues were analyzed from sites in the grassland, n=76, and transition zone, n=69.

Figure 24. Plot of PRIN1 versus PRIN2 scores for identified archaeological residues from parkland sites.

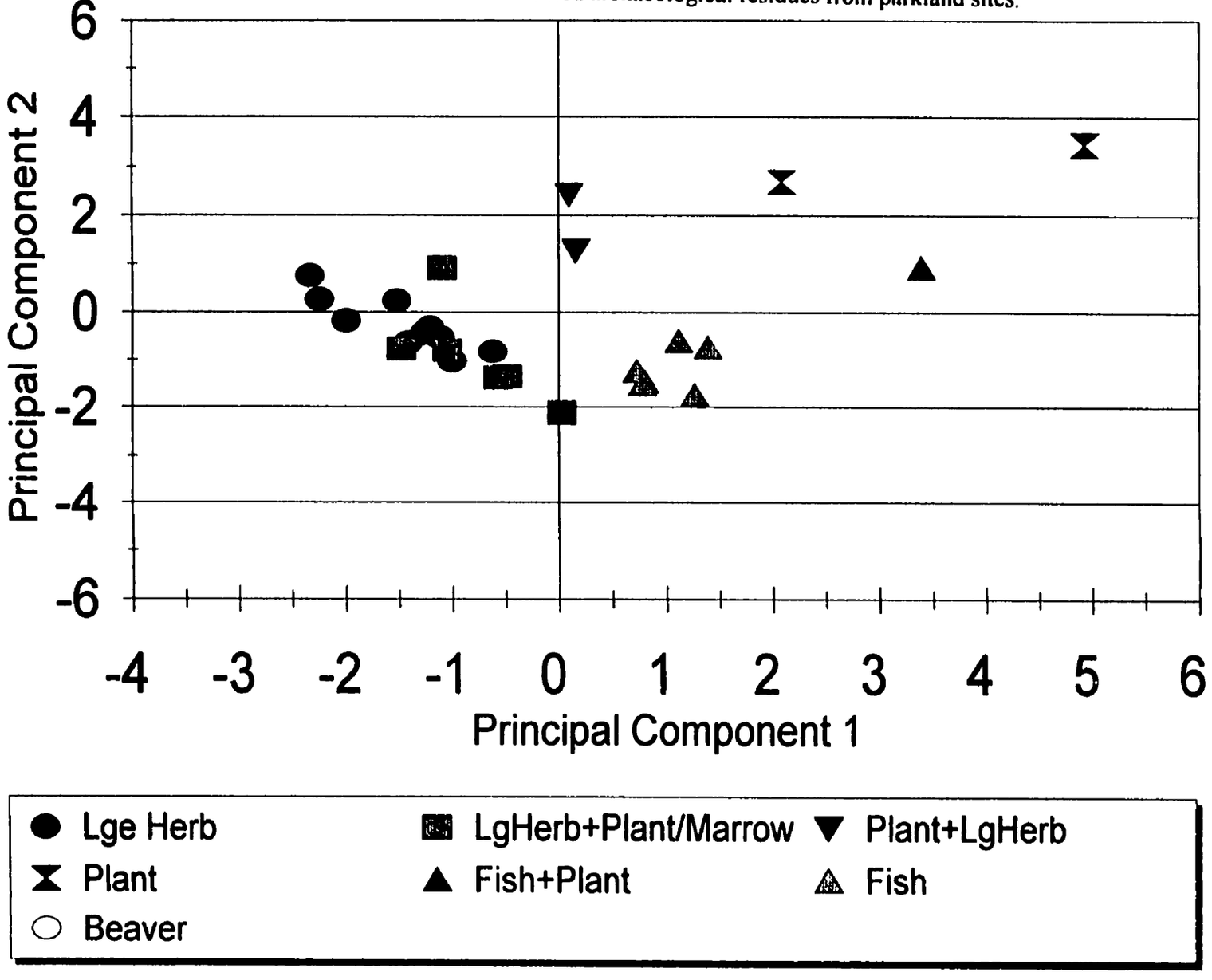


Figure 25. Plot of PRIN1 versus PRIN2 scores for identified archaeological residues from forest sites.

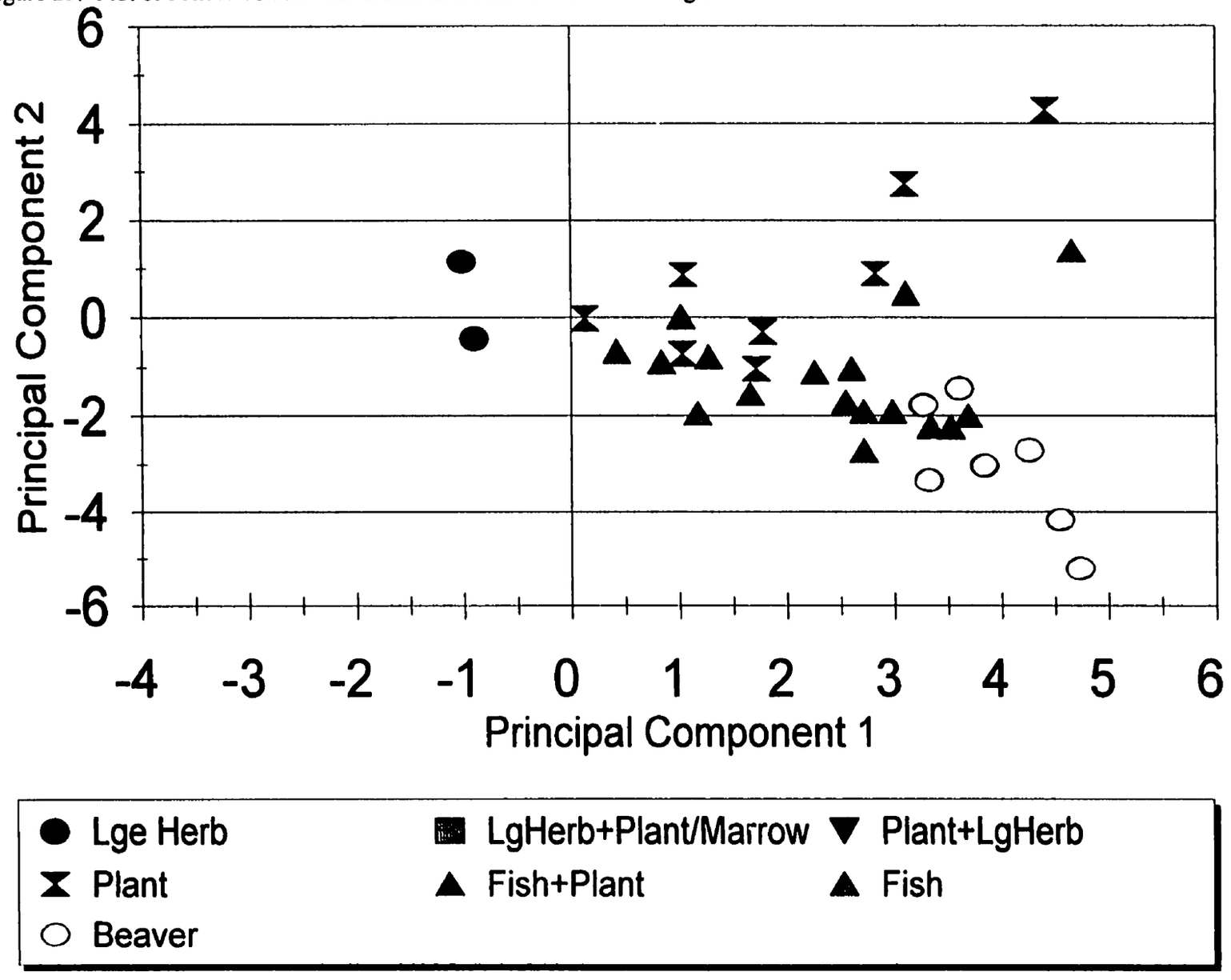


Table 13. Summary of residue identifications for each vegetation zone.

Identified Residue	Grassland		Transition		Parkland		Forest	
Large Herbivore	55	72.4%	48	69.6%	10	37.0%	2	5.9%
Large Herb. and Plant or Bone Marrow	3	3.9%	3	4.3%	6	22.2%	-	-
Plant and Large Herb.	6	7.9%	2	2.9%	2	7.4%	-	-
Plant	9	11.8%	7	10.1%	2	7.4%	8	23.5%
Fish and Plant	1	1.3%	4	5.8%	1	3.7%	4	11.8%
Fish	1	1.3%	3	4.4%	6	22.2%	13	38.2%
Beaver	1	1.3%	2	2.9%	-	-	7	20.6%
TOTALS	76	100%	69	100%	27	100%	34	100%

About 70% of residues from both grassland and transition zone sites were identified as large herbivore. The percentage of residues identified as plant, about 10%, and large herbivore with plant or marrow, about 4%, are also similar. Residues from transition zone sites differ from those of the grassland in terms of the higher occurrence of fish or corn, alone or with plants in the former zone. More than 10% of transition zone residues show evidence of fish or corn as opposed to only 2.6% of grassland vessel residues. There is a sharp increase in the presence of fish or corn in vessel residues from parkland and forest sites. Over 22% of parkland vessel residues show evidence of fish or corn in the residues, this increases to over 38% in vessel residues from forest sites. Vessels used to prepare fish and plant together form 3.7% of the parkland sample but almost 12% of the forest residues. About 15% of parkland vessel residues result from cooking plants; almost 30% of vessels from forest sites were used for this purpose. Large herbivores appear in 37% of

parkland residues alone, but in almost 30% of residues together with plants or as marrow. The importance of large herbivores appears to be very low in forest sites but more than 20% of forest vessels have residues which most closely resemble beaver in composition.

Comparisons between site assemblages within each vegetation zone show that high levels of similarity exist (Table 14). The presence of foetal bison remains establishes seasonality in five of the seven grassland sites: Sanderson, Morkin, Ross, Head-Smashed-In and Garratt. Strong indicators are lacking at the Sjovold site but the two layers from which pottery samples were taken are considered to be warm season occupations. Seasonal data is not available from the Long John site. The faunal assemblages from all these sites are dominated by bison remains and hunting is the major economy.

Other species, including canids, deer, bear, rabbits and birds, are present in such small numbers their food value is difficult to assess. As noted in section 4.2.2, dogs were considered second only to bison in terms of native food preferences. Dogs were clearly an important source of food in some Precontact sites in Nebraska where butchered and burnt canid bones represent about 30% of the identifiable faunal remains (Snyder 1991). At the Ross site, however, canid, bird, and fox bone were clearly used for bead production while bear claw and mollusc shell were used for pendants (Vickers 1989); bird bone was used for bead production at the Garratt site (Morgan 1979).

Vessel residue identifications from these sites correspond with evidence from the faunal and tool assemblages (Table 14). The vast majority of residues from each grassland site were identified as large herbivore; it was the only type of residue found in vessels from Head-Smashed-In. Residues identified as large herbivore with plant or marrow, or, plant

Table 14. Faunal remains, economy and seasonal indicators of sites under investigation.

Site	Zone	FAUNAL REMAINS				ECONOMY		SEASONALITY INDICTORS			
		Bison	Canis	Fish	Other	Hunting	Fishing	Foetal Bison	Fish Annulus	Fish/Bird Migration	Inferred Only
Sanderson	Grassland	Major	tr	---	tr	Major	---	YES	---	---	
Morkin	Grassland	Major	tr	---	tr	Major	---	YES	---	---	
Ross	Grassland	Major	minor	---	minor	Major	---	YES	---	---	
HSI	Grassland	Major	tr	---	tr	Major	---	YES	---	---	
Long John	Grassland	Major	N/A	N/A	N/A	Major	---	N/A	---	---	N/A
Sjovold	Grassland	Major	tr	tr	tr	Major	tr	---	---	---	warm
Garratt	Grassland	Major	minor	---	minor	Major	---	YES	---	---	
Lowton	Transition	Major	tr	---	tr	Major	---	N/A	---	---	year round
Lake Midden	Transition	Major	minor	minor	minor	Major	Minor	YES	---	---	
Stott	Transition	Major	minor	minor	minor	Major	Minor	YES	---	---	
Hartley	Transition	Major	minor	tr	minor	Major	tr	YES	---	Spring	
Lebret	Transition	Major	---	Major	minor	Major	Major	N/A	---	Spring	
Lovstrom	Transition	Major	minor	minor	minor	Major	---	N/A	---	---	warm
Bushfield West	Parkland	Major	minor	minor	Beaver	Major	Minor	YES	N/A	Spring	
Lockport	Parkland	Major	tr	Major	minor	Major	Major	---	N/A	Spring	
Aschkibokahn	Forest	tr	tr	Major	Moose	Major	Major	---	Spring	Spring	
Cabin Point	Forest	----	tr	minor	Moose & Beaver	Major	Minor	---	N/A	---	warm
Black Fox Is.	Forest	----	tr	minor	Beaver, Hare and land mammals	Major	Minor	---	N/A	---	warm

Table 15. Vessel residue identifications for each site

Site	n =	Lg. Herb.	Lg. Herb. & Plant or Marrow	Plant & Lg. Herb.	Plant	Fish &Plant	Fish/ Corn	Beaver
Sanderson	**15**	11	1	-	1	1	1	-
Morkin	**13**	10	-	2	1	-	-	-
Ross	**13**	8	-	3	2	-	-	-
HSI	**4**	4	-	-	-	-	-	-
Long John	**14**	13	-	-	1	-	-	-
Sjovold	**4**	2	1	-	-	-	-	1
Garratt	**13**	7	1	1	4	-	-	-
Lowton	**14**	13	-	1	-	-	-	-
Lake Midden	**16**	12	-	-	3	-	1	-
Stott	**15**	12	1	1	1	-	-	-
Hartley	**9**	6	1	-	-	1	-	1
Lebret	**12**	3	1	-	3	3	1	1
Lovstrom	**3**	2	-	-	-	-	1	-
Bushfield West	**19**	7	5	2	2	1	2	-
Lockport	**8**	3	1	-	-	-	4	-
Aschkibokahn	**18**	-	-	-	4.5	-	11.5	2
Cabin Point	**15**	2	-	-	3	3	2	5
Black Fox Is.	**1**	-	-	-	1	-	-	-

with traces of large herbivore were found at all grassland sites, except Long John. Residues identified as plant alone were found in vessels from all other sites, except Sjovold. The residue from one Sjovold vessel was identified as beaver. One vessel residue from the Sanderson site was identified as fish or corn while another appears to be fish or corn with plant. No fish remains were associated with cultural materials at the site and the proximity of the site to the Missouri River Villages increases the possibility that corn could have been prepared in these vessels. The inability to discriminate between fish and corn using fatty acid composition represents a shortcoming of this technique.

The presence of foetal bison remains at transition zone sites, Lake Midden, Stott and Hartley, established that they were occupied during the winter and early spring. The Stott site, however, was occupied at different times and perhaps different seasons as well. On the basis of the spawning season of fish, the Lebret site was probably occupied in the spring. Seasonal indicators are absent from the Lowton and Lovstrom sites but Nicholson (1994) suggests that Lovstrom was inhabited during the warm season and Lowton was occupied throughout the year. Bison remains and tools associated with a hunting economy are well represented in transition zone sites (Table 14); but there is an increased occurrence of fish remains and tools associated with a fishing economy. Materials from six transition zone sites were considered; fish remains and/or tools associated with fishing were recovered from four: Lake Midden, Stott, Hartley and Lebret. No fish remains were recovered from the Lovstrom site. A representative faunal sample is not available from the Lowton site. The vessel residues from transition zone sites reflect evidence gleaned from the faunal and tool assemblages. Most of the vessel residues from sites where bison

bone and the hunting economy dominates were identified as large herbivore. Both bison and fish remains were common at the Lebret site and large herbivore products and fish or corn, alone or in combination with plants were each detected in 4 of the 12 samples. Fish or corn was also identified in residues from Lake Midden and Lovstrom; fish or corn with plant was found in one vessel from the Hartley site. Residues identified as large herbivore in combination with plant or as marrow were found at Stott, Hartley and Lebret. Vessels from Lake Midden, Stott and Lebret appear to have been used to cook plant alone. One residue each from Hartley and Lebret was identified as beaver.

Vessel residues from two parkland sites, Bushfield West and Lockport, were considered. Foetal bison bone was found at Bushfield West but the presence of migratory birds and egg shell suggests the occupation continued into late spring. A wide variety of large mammals, small mammals, birds and fish remains were found at the site. Similarly, the vessel residues from Bushfield West were the most diverse of any site examined. Seven vessels were used to cook large herbivore alone; another seven residues were large herbivore in combination with plant material or as marrow. Two vessel residues were identified as plant; two more were fish or corn and another was fish or corn with plant.

The spawning season of fish and the migration of birds suggests that Lockport was occupied during the spring but it was likely inhabited at other seasons. Charred corn, bison scapula hoes and bell-shaped storage pits on the east side of the river attest to the presence of horticulture. Fish and large mammals were the most important sources of meat, but problems with stratigraphy may have resulted in the mixing of material from the horticultural occupation with an earlier Blackduck occupation. The sherds examined in

this study are from an isolated horticultural occupation on the west side of the Red River, referred to as Lockport West. The residues from these vessels indicate that fish or corn (n=4), large mammals (n=3) and large mammals with plant or as marrow (n=1) were important to the westside inhabitants. Once again, the inability to discriminate fish from corn hampers our ability to interpret site activities as both items have equal probability of appearing in these cooking pots.

Sherds from three forest sites, Aschkibokahn, Cabin Point and Black Fox Island, were examined. Fish and moose were the two main sources of food at Aschkibokahn. Hanna's (1980) analysis of fish scales from the site indicates almost all were harvested in the spring during spawning season. This emphasis is reflected in the vessel residues; at least 11 of the 18 residues were identified as fish or corn. A broad range of plant material was available during the warm season but only uncharred seeds were recovered from the site, which could have been deposited naturally. Regardless, the vessel residues indicate that plants were prepared in at least four vessels. One residue had an equal chance of being fish or plant. Two residues most closely resemble beaver in composition.

There was a predominance of beaver and moose in the faunal material of Cabin Point, but the remains of muskrat, snowshoe hare and traces of a variety of other medium sized mammals were found. Mollusc, fish (primarily sturgeon), bird and turtle remains were also recovered (Grainger 1980). A wide variety of plant seeds and berries were recovered from the site, including goosefoot, wild rice, rose, knotweed, sarsaparilla and pincherry and hazelnut suggesting a warm season occupation, lasting into late summer (Zoltai 1989). The residues at the site include five identified as beaver; three identified as

plant, two as fish or corn and three as fish or corn with plant.

The faunal remains from Black Fox Island were highly fragmented, which reduced the amount of identifiable bone in the collection (Connor-Learn 1983). The remains of beaver, snowshoe hare, northern pike and whitefish were identified. Unspecified large land mammals, small land mammals and bird were also found. Residue from the one vessel recovered from the site was identified as plant.

9.5 Summary

Archaeological vessel residues are highly decomposed and can not be identified through direct comparison with modern foods; but decomposed experimental cooking residues can provide the basis for defining the identification criteria. High levels of C18:0 indicates the presence of large herbivore; high levels of C18:0 together with elevated levels of C18:1s suggests that large herbivore and plant material or marrow is present. Levels of C18:0 below 25% suggest either fish or plants were prepared in the pots. This feature, together with C18:1s levels ranging from 15% to 30%, and a low level of medium chain fatty acids suggest fish was prepared in the vessel; higher levels of medium chain fatty acids indicates both fish and plants were cooked. Low levels of C18:0 and C18:1s but high levels of medium chain fatty acids is a characteristic of plant residues. Samples with very high levels of C18:1s and low levels of C18:0 most closely resemble beaver. The usefulness of these criteria for discriminating significant groups in the data is supported by the results of the hierarchical clustering and principal component analysis.

The distribution of identified residues at each site corresponds with the evidence from the faunal and tool assemblages. The vast majority of vessel residues in grassland

sites were identified as large herbivore; many were identified as marrow or large herbivore in combination with plants or as plants alone. Only a small percentage were identified as fish or corn, alone or with plants. The majority of the faunal remains from these sites are bison and the tool assemblages attest to a hunting economy. Similarly, most residues from transition zone sites were identified as large herbivore, but the occurrence of residues representing fish or corn alone or with plants increases to about 10%. Except for the Lovstrom sample, all residues containing fish or corn were from sites containing fish bone and/or fishing tools, such as harpoons.

The occurrence of large herbivore residues decreases while those of fish or corn increase in parkland sites. The inability to discriminate fish from corn is unfortunate, particularly for the Lockport samples, as both foods were likely prepared at this site. Fish or corn, alone or with plants, predominates the residue identifications at two forest sites, Aschkibokahn and Cabin Point. The faunal and tool assemblages from Aschkibokahn strongly support the identification of fish in the vessel residues. Some vessels appear to have been used to prepared beaver, a common forest food. Vessel residues identified as plant are common, but large herbivore is not often detected in the residues. Faunal remains from both of these sites indicate that moose was exploited so it is possible the meat was cooked in way which would not produce vessel residues. David Thompson (1962:63) reports that, when boiled, moose flesh becomes weak and watery without producing a good broth; "the change is so great, one can hardly be persuaded it is the meat of a Moose Deer." If forest-adapted people shared Thompson's assessment, moose would have likely been prepared by roasting and, therefore, not detectable in pot residues.

Chapter 10. Conclusions

Archaeologists agree that the seasonal movement of bison had a determining effect on the settlement pattern of those who strongly depended on them. In general, the open grasslands are regarded as unsuitable for occupation during the winter; the shelter, forage and fuel available in the parkland is considered to have attracted plains bison (Moodie and Ray 1976; Morgan 1979; Gordon 1979; Meyer and Epp 1988) and hunter-gatherers from surrounding vegetation zones (Ray 1974; Syms 1977; Pettipas 1980; Nicholson 1988; Smith 1988; Meyer and Epp 1990, Vickers 1991). In late winter and early spring, when these bison were lean and returning to the plains, hunter-gatherers utilized other food resources, such as fish.

Most scholars discuss late Precontact and early Postcontact settlement and subsistence activities in terms of modern or reconstructed vegetation zones; however, significantly different patterns emerge when historical accounts of bison movements and winter camp locations are compared to the actual nineteenth-century vegetation limits. The boundaries of the plains, parkland and boreal forest delineated by Hind (1971) in 1860 are consistent with earlier observations by Europeans. The parkland was previously narrower and situated north of its present location. Historical accounts indicate that relatively few bison entered treed areas compared to the vast numbers observed on the grasslands. Plains-adapted peoples usually wintered far out in the open grasslands, where the concentration of bison was very high, in order to facilitate communal hunting. Most winter camps were situated in river valleys; although some were established on the open prairie, even on the tops of hills. Parkland- and forest-adapted peoples moved to the

grassland-parkland transition zone to gain access to smaller, transient herds on the northern edge of the wintering range. The movements of these bison varied, with the degree of penetration into the parkland depending largely on the severity of the weather.

Archaeological evidence supports these observations as several sites found on the open grasslands and the grassland-parkland transition zone contain foetal bison bone, suggesting they were occupied in late winter or early spring. Few sites in the parkland and forest were occupied in winter; rather, they represent fall or spring occupations.

It is proposed that the subsistence and settlement strategy of plains-adapted hunter-gatherers focused on the exploitation of bison in the grasslands throughout the year. This behaviour is consistent with optimal foraging models of hunter-gatherer subsistence and settlement. Bison was the favourite food of plains-adapted peoples and provided materials for shelter, clothing and tools; therefore, it had a very high utility index. The most efficient way to procure bison was through communal hunts and some large-scale hunts involved the cooperation of hundreds of people from different bands. Cultural materialism provides a means of illustrating how this settlement and subsistence strategy enhanced their political and domestic economies as well as their behavioral superstructure. The resulting band aggregations provided a venue for establishing or reenforcing kinship ties through marriage which would strengthen trade links and political alliances. The production of bone beads at several sites is consistent with preparations for ceremonial activities. These rituals propagate the ideologies, myths and philosophies of the social group.

It was necessary for plains-adapted hunter-gatherers to establish their winter

camps deep in the grasslands as this is where herds of wintering bison were most plentiful. In late winter and spring, the lean meat of fat-depleted adults was avoided by exploiting other favourites, foetal and newborn bison, for food. By switching to young bison, a source of fat-rich food was obtained without changing the standard method of procuring food. Fish was not a desirable food item; although rivers were full of spawning fish, they were not harvested in the spring. Furthermore, three independent accounts indicate that a sudden switch from lean red meat to fish resulted in deleterious physical effects. The symptoms experienced, including diarrhea and weakness, are consistent with fat malabsorption.

The strategy of remaining close to large, stable bison herds is important to plains-adapted groups for several reasons. Plains-adapted hunter-gatherers maximized their access to bison, their favourite and most versatile food source. They diminished the risks associated with eating lean meat by utilizing young bison in late winter and spring. By maintaining their supply of bison, they decreased the need to exploit other resources, such as fish. When their winter camps were located in sheltered river valleys, the risks associated with severe weather on the grasslands were reduced.

The parkland- and forest-adapted groups formed their winter camps on the margins of the range of wintering bison, generally the transition zone between the grasslands and the parkland. This strategy was advantageous because it enabled them opportunistic access to wintering bison while minimizing their incursions onto the plains. In an average winter, camps were formed in aspen groves on the northern edge of the grassland, which afforded shelter and a supply of wood for fuel. In a mild winter when

bison remained far out in the open grasslands, these groups had the option of either exploiting different resources, such as deer, elk and moose, or moving deeper into the plains. Under these circumstances, the benefits of having access to wintering bison were balanced against the risk of encountering potentially hostile plains groups and severe weather on the plains. In late winter and early spring, when the transient herds moved farther into the grasslands and out of hunting range, a variety of other food resources, such as dried meat, pemmican, and spawning fish, were exploited. With the bison gone, these groups gradually returned to their home territories in the parkland and forest and continued their diverse strategy.

Under the plains adaptive strategy, the benefit was maximum access to bison at the expense of shelter and fuel sources. By forming camps in river valleys, plains-adapted people were able to reduce the hazards posed by severe weather. Under the parkland and forest adaptive strategies, the benefit was ready access to shelter and fuel sources at the expense of access to wintering bison. With only opportunistic access to bison, the need for parkland- and forest-adapted hunter-gatherers to follow a diverse diet and have a supply of stored foods was likely high.

The faunal remains, tool kits and more than 200 cooking residues from eighteen grassland, transition zone, parkland and forest sites support the validity of the proposed hypotheses. Evidence from grassland sites indicates the inhabitants followed a hunting economy and bison supplied most of their nutritional requirements. There is little or no evidence of fish use in the faunal remains, tool kits or cooking pot residues.

The very presence of formed foetal bison bone in grassland archaeological sites is

perhaps the most compelling evidence that the Precontact plains-adaptive strategy was different from parkland- and forest-adapted peoples. Foetal bison bone in grassland camps indicates a mid- to late winter occupation and this is precisely the period when the number of wintering bison approaching the parkland peaked and began to decline. In order to benefit from their effort, a movement of plains-adapted people to the parkland would have had to take place in the fall and this clearly did not occur. The foetal bison bone in plains sites also supports Fidler's (MacGregor 1966) observation that these animals were taken for food in late winter when the adults were fat-depleted. The lack of fish in grassland cooking pot residues is consistent with the lack of fish bone and fishing implements from these sites and together provide strong evidence that plains-adapted peoples did not regularly utilize this resource.

The inhabitants of transition zone sites also followed primarily a bison hunting economy over the winter, but the diet breadth was wider than that exhibited in grassland sites. While there is some evidence of fish or corn use at many sites, it appears to have been especially important to the former inhabitants of the Lebret site. The need to use fish for food at the Lebret site is supported by the historic account of Daniel Harmon (1957), who noted that few bison, deer or moose were found in the vicinity of the Fishing Lakes in the winter of 1804.

Evidence from the five parkland and forest sites examined suggests they were occupied in the spring. The faunal remains, tools and cooking pot residues all indicate a mixed hunting and fishing economy was followed. The placement of winter camps in the transition zone between the grassland and parkland, rather than in the parkland itself

supports the proposed parkland- and forest-adaptive strategies. Again, the presence of foetal bison bone is the primary indicator that transition zone sites were occupied in mid- to late winter. The economy is dominated by bison hunting but traces of fishing equipment, fish bone and fish or corn residues in the cooking pots are found, suggesting that site occupation may have extended into spring. With the departure of bison, there was little incentive for these groups to remain in the transition zone. Groups planned their movement back into the parkland and forest in order to take advantage of spring resources which included spawning fish, migrating birds and, if available, drowned bison. Postcontact forest groups timed their return from the transition zone according to preparations for the canoe trip to the trading houses on Hudson's Bay (Russell 1991).

While faunal remains and tool assemblages are traditional sources of information about subsistence strategies, the examination of cooking pot residues represents an innovative approach. Gas chromatographic analysis has proven to be a highly effective method of characterizing the fatty acid content of the absorbed cooking pot residues. By using identification criteria based on the compositions of degraded experimental cooking residues, it was possible to classify most of the archaeological vessel residues into one of seven categories: 1) large herbivore alone, 2) large herbivore as marrow or with plant, 3) plant alone, 4) plant with traces of large herbivore 5) fish or corn alone, 6) fish or corn in combination with plant and 7) beaver. The results of the residue analysis represent a source of information about the subsistence practises of the site inhabitants completely independent from faunal remains and tool assemblages. While direct or indirect evidence of large herbivores and fish can often be gleaned through the bones and artifacts recovered

from the site, vessel residue analysis has the ability to provide direct evidence of plant use. In the case of poor preservation of faunal remains and bone tools, vessel residue analysis provides an important avenue for obtaining evidence of subsistence patterns.

The inability to discriminate between fish and corn on the basis of fatty acid composition, however, represents a significant limitation of this technique. Traditional sources of information, including paleobotanical studies, tool assemblages, faunal remains and proximity to horticultural villages, allow one to make an educated guess as to which substance is more likely to have appeared in the cooking pots at a given site. This approach can not be employed at the Lockport West site as the remains of both corn and fish were recovered. In such cases, sterols in the residues analyzed using GC/MS may provide a precise identification. The presence of cholesterol in the residue indicates animal origin while campesterol and sitosterol are characteristic of plant tissues (Evershed 1993). If carbonized residues were available, fish could be discriminated from corn on the basis of $\delta^{13}C$ and $\delta^{15}N$ isotopic analysis and carbon and nitrogen ratios (Hastorf and DeNiro 1985; Morton 1986; Sherriff *et al.* 1995).

In spite of this limitation, fatty acid analysis using gas chromatography is very useful for establishing the material of origin for archaeological cooking pot residues. Gas chromatography utilizes the unique chemical and physical properties of the different fatty acid methyl esters to separate the components in a sample. When run under identical conditions, the same fatty acids in different samples will emerge from the column at the same time. This enables the fatty acids to be identified by comparing the sample chromatograms with chromatograms of known standards. Possible contaminants

introduced from the burial environment or subsequent archaeological processing were eliminated by grinding off the surfaces of the sherd. While the impact of solvent contamination increases in highly concentrated samples, adjustments can be made by running solvent and chemical blanks, determining the nature and degree of fatty acid contaminants, and then subtracting them from the sample peaks. As any manipulation of the data introduces a potential source of error, sherds expected to have a high concentration of absorbed lipids should be selected for analysis. In cases where food was prepared in the vessel by boiling, the neck and shoulder areas of the pot will have the highest concentrations of absorbed lipids.

Cooking and decomposition experiments showed that very long chain saturated and polyunsaturated fatty acids are most susceptible to oxidation and thermal degradation, but the relative percentages of medium chain fatty acids (12:0, 14:0 and 15:0), C18:0 and C18:1s can be used to identify the residue. While compositional differences between plants, roots, berries and seeds tend to disappear, archaeological vessel residues with relatively high levels of medium chain fatty acids combined with low levels of C18:0 and C18:1s can be identified as plant. Very high levels of C18:1s in the residue together with low levels of C18:0 suggest that beaver was prepared in the pot. The polyunsaturated fatty acids in fish also disappear but low levels of medium chain fatty acids and C18:0 combined with moderate levels of C18:1s are characteristic; combinations of fish with plant are indicated by higher levels of medium chain fatty acids in the residues. High levels of C18:0 in the residue indicates the presence of large herbivore. Both bone marrow and large herbivore meat prepared with plants, such as berries and greens have high levels of

C18:0 and C18:1 isomers. Higher levels of C18:0 in plant cooking residues likely indicates there are traces of large herbivore.

Analysis of the experimental cooking residues also demonstrated the effects of thermal and oxidative degradation on fatty acid compositions. With the disappearance of most polyunsaturated fatty acids, the relative concentrations of the remaining fatty acids increases. In particular, the amounts of saturated fatty acids, such as C16:0, rise dramatically. Adipocere formation was not a factor in the increased levels of C16:0; rather, the increase results from the presentation of the fatty acid composition as relative percentages.

Further research will lead to refinements in the identification of archaeological vessel residues through GC analysis; in particular, the preparation and decomposition of more experimental cooking residues are required. This first application of GC analysis to Late Precontact Period pottery demonstrates that a 10 g neck or shoulder sherd can provide valuable information about the use of a cooking vessel which, until now, has remained elusive. Vessel residues, combined with faunal and tool analysis, can successfully be used to address archaeological problems, including the testing of hypothesized Precontact settlement and subsistence strategies.

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Appendix A: General Site Descriptions

A.1 Grassland Sites

A.1.1 Sanderson Site

The Sanderson site, DhMs-12, was situated on the south bank of the Souris River Valley on McDonald Lake, near Estevan, Saskatchewan. Saskatchewan Research Council archaeologists conducted excavations at the site in the late 1980s prior to it being flooded by the Rafferty Dam reservoir. It is a multicomponent site, but only the upper Mortlach component was excavated as part of the site mitigation. A radiocarbon date of 310±75 BP was obtained. Based on the presence of a glass trade bead, the uppermost Mortlach component likely dates to the early stages of European contact. Due to the large amount of bison remains, Sanderson was initially considered to be a kill site, but further excavations indicated it was a campsite. Although no site report is available, Sanderson site pottery has been identified as Mortlach (Malainey 1991; Walde 1994).

The faunal assemblage from Block 7 West is currently being analyzed by Michael Magee, as his Master of Arts research at the University of Saskatchewan. Magee (1997) reports that animal remains from this part of the site are dominated by bison, which makes up about 99% of the faunal assemblage; foetal bison are common. The remains of dogs, coyote, swift fox, jackrabbit, beaver, mink and a variety of other small mammals were found. Bird bones recovered include swan, goose, mallard and blue-winged teal. Breakage patterns of the bison bones suggests they were butchered when frozen (Magee 1997). The presence of foetal bison bone also indicates the site was occupied in winter, but the presence of bird bone suggests it may also have been inhabited in the fall. A few

fish remains were found at the site but do not appear to be directly associated with the precontact occupations. These bones may have originated with the mink, a fish-eating carnivore, or, represent contamination from a historic fishing station located in the area (Michael Magee, personal communication, 1997). While no evidence of cultigens were found in the palaeobotanical study conducted by Shay *et al.* (1995), they were able to establish the former inhabitants of the Sanderson site used a variety of plants for food. Charred seeds found at the site include bulrush, knotweed, marsh elder and dock, but goosefoot was the most abundant and widespread. The most abundant fruit and berry remains at the site were wild rose, hawthorn and wild cherry.

A.1.2 Morkin Site

The Morkin site, DlPk-2, is a buried campsite on the lowest terrace of Trout Creek Valley, bounded on three sides by the stream and on the fourth, the west side, by the valley wall. Major excavations were conducted at the site from 1967 to 1970. Five major stratigraphic levels have been identified with radiocarbon dates extending from AD 610 ± 130 at the bottom to AD 1845± 90 at the top. A number of precontact excavated features, such as prepared hearths and refuse pits including a large bell-shaped pit were identified. Other features include stone and/or bone concentrations, a clay lens and bone uprights. A detailed analysis of faunal materials is not available and adult bison bone does not appear to have been processed. Several boxes of uncatalogued faunal remains from this site primarily contain adult bison bone (Bob Dawe, personal communication 1997). Quigg (1978) reported that foetal bison bone was found at the site; the author's perusal of the catalogue records reveals that more than 130 foetal bison bones were recovered from

the different levels. Similar amounts of canid bone were identified with another 50 bones identified as probably canid. About 25 bones may be kit fox while a few others were either jackrabbit or kit fox. Traces of deer or antelope, beaver, elk, ground squirrel and bird were also recovered. Several bone beads were found, five of these were identified as bird bone.

While projectile point types were distributed throughout almost all levels, definite concentrations exist. Besant points were primarily found in Levels 4 and 5; Avonlea points were concentrated in Levels 3 and 4. Side-notched projectile points were common in the three uppermost levels, most were found in Levels 2 and 3. Plains Triangular points were the most widely distributed, representing between 24% and 36% of all points recovered from Levels 2 to 5. A small number of historic trade and aberrant points were found in Levels 1 and 2. In addition to more than 500 projectile bones, over 3000 worked stone, bone and shell tools were also found at the site (Byrne 1973:1).

Pottery recoveries were quite well restricted stratigraphically. The bulk of the classifiable sherds (1510 of 2310 or 65.4%) were recovered from Level 2. Smaller amounts were found in Levels 1 (n=186), 3 (n=264) and 4 (n=320). A few sherds were recovered from the surface (n=21) and Level 5 (n=9). Byrne (1973) used the pottery recovered from this site as the basis for the definition of Saskatchewan Basin pottery. The Early Variant of the pottery is associated with Avonlea materials and the Late Variant is associated with the Old Women's phase. The 14 potsherds selected for analysis are Late Variant Saskatchewan Basin.

A.1.3 Ross Site

The Ross site, DlPd-3, is situated on the Oldman River near Coaldale, Alberta, where the valley bottom is unusually wide and rich in woods. Vickers (1989:3) describes the Ross site locale as "a pleasant, wooded oasis below the windswept plains". It was first excavated in 1957 by Richard Forbis (1960), who identified the main component, Layer III, as a winter camp occupied between AD 1500 and AD 1700. Almost one-half (731 of 1504 or 49%) of all collected artifacts were lithic, mainly projectile points and point fragments, 46% were potsherds from at least seven different vessels and the remaining 5% were bone tools and shell. Byrne (1973) identifies the pottery from this site as Late Variant Saskatchewan Basin Complex. A possible cache of lamb's quarters (goosefoot) seeds was also discovered. Faunal material was not collected in the 1957 excavation.

In order to assess the effect of erosion on the site, two additional 2 x 2 m units were excavated at the site in 1980 (Vickers 1989). Vickers (1989:44) renamed the main occupation, Component III, a 8 - 10 cm thick layer, possibly representing 2-3 closely spaced occupational events. Features included a hearth and a pit tightly packed with bison bone and fire broken rock, identified as a roasting pit subsequently used for refuse. The majority of faunal remains were bison (n=342) and canid (n=177); the bones of deer (n=3), rabbit/hare (n=1), bear (n=1), fox (n=1), unidentified bird (n=3) and fragments of shell were also present. Not all faunal material recovered from the site relates to diet, however. Canid metapodials, as well as, the fox and rabbit remains provided raw material for bone bead production. The bear claw was pierced to enable suspension. Five shell beads were also found in Component III. Most of the bone fragments not identifiable to species were

from large mammals, likely bison (Driver 1989:150). Foetal bison remains recovered from the site included 10 bones representing a minimum of two animals; 9 small pieces of ossified cartilage may also have been from foetal bison (Driver 1989:143).

Only fourteen sherds were recovered from the site in 1980, 13 from Component III and one from Component I. For this reason, the thirteen sherds selected for residue analysis were from Forbis' 1957 excavation. Based on surface finish, temper and paste characteristics, each probably represents a unique vessel.

A.1.4 Head-Smashed-In

Head-Smashed-In, DkPj-1, is a bison jump located in southwest Alberta at the southern end of the Porcupine Hills. After hundreds of kill episodes, the accumulation of bone and stone tools at the bottom of the sandstone cliff measures 11 metres deep. While the earliest use of the jump dates back thousands of years, the most intensive utilization was during the Late Precontact period. In the mid-late 1980s, excavations of the camp and processing area on the prairie level 200 m downslope and southeast of the main kill site were undertaken. The samples taken for residue analysis are Late Variant Saskatchewan Basin, otherwise known as Old Women's Complex, pottery recovered from the camp and processing area in the late 1980s. The findings of these excavations were similar to the results of the 1985/1986 excavation of a 25 square metre block and are presented in Brink and Dawe (1989).

In the course of the 1985/1986 investigation, a number or bone uprights and pit features were identified. The majority of projectile points were Old Women's (mainly Plains and Prairie side-notched), with a smaller number of Avonlea and triangular

preforms also present. A variety of knives, scrapers, drills, abraders, hammerstones, and assorted other stone tools were found. Bone tools recovered at the site include dog and fox remains representing beads and the waste of bone bead production, an awl probably manufactured from a canid fibula, buttons, gaming pieces and bison rib and long bone fragments polished from use (Brink and Dawe 1989:288-290).

As expected, the vast majority of faunal remains were identified as bison but many of the bones are highly fragmented. In the 1985/1986 excavation of the block area, 25 foetal bison remains were recovered from the site (Brink and Dawe 1989:155-156). Traces of non-bison remains include canids (dog, wolf and coyote), Richard's ground squirrel and mule deer (Brink and Dawe 1989:79).

A.1.5 Garratt

The Garratt site, EcNj-7, is located on the flood plain of Moose Jaw Creek, within the city limits of Moose Jaw, Saskatchewan. Excavations at the site were conducted by Saskatchewan Museum of Natural History, now the Royal Saskatchewan Museum, personnel in 1966, 1968 and 1969. It is a multicomponent site containing a Late Plains occupation in Levels 1, the ploughzone, and Level 2, *in situ* deposits below the ploughzone, an Avonlea occupation in Level 6 and Besant materials in Level 8 (Morgan 1979:89-90). A small amount of European artifacts were also recovered but it is not known if they are historic trade items or items deposited by later settlers (Morgan 1979:293).

The sherds selected for residue analysis are all from the Avonlea occupation, Level 6. Ten vessels were identified from the Avonlea occupation; globular and conoidal

vessels with plain and net-impressed exterior surface finishes were found. The remains of at least 12 bison were found in the Avonlea level; foetal bison bones were recovered from Level 6 but their frequencies are not presented (Morgan 1979:96). Non-bison, faunal recoveries include a minimum of five ground squirrels, four kit foxes, three skunk, two grey wolf, two birds as well as at least one coyote, unidentified canid, porcupine, jack rabbit, pocket gopher, beaver, deer and badger. Over 100 pieces of mollusc shell was recovered from the Avonlea occupation; no fish remains were recovered.

The lithic assemblage of the Avonlea occupation includes 19 Avonlea, 29 Avonlea Triangular and one Besant projectile point. A variety of bifaces, unifaces, choppers, a pestle, hammerstones, cores and lithic debitage were recovered, as well. Bone tools include five awls or perforators and one hide flesher.

A.1.6 Long John

The Long John site, EeNj-1, is located on Buffalo Pound Lake, north of the city of Moose Jaw, Saskatchewan. It is situated in a coulee which enters the Qu'Appelle Valley near a permanent spring and has been identified as a kill and butchering site. Plains-side notched points, scrapers and bifaces have been recovered. Professional archaeologists have conducted only limited testing of this site. Much of the material from this site was contributed to the Royal Saskatchewan Museum by avocational archaeologists. The sherds used in this study were donated to the museum by Doug Warren, who had a large collection of material from this site. Over a period of several years, he partially reconstructed many pots from the site; as such, the level of vessel integrity in this collection is among the highest observed for a Saskatchewan site. Both Malainey (1991)

and Walde (1994) identify the pottery as Mortlach.

A.1.7 Sjovold

The Sjovold site, EiNs-4, is a deeply stratified, multicomponent site situated on the west bank of the South Saskatchewan River at the mouth of a small creek valley, near Outlook, Saskatchewan. The site was excavated in 1979 and 1980 by the staff of the Royal Saskatchewan Museum, formerly the Saskatchewan Museum of Natural History, under the direction of Ian Dyck. More than twenty occupations were identified, vessels from three short-term, Late Precontact occupations were included in this study. The Sjovold 1 is from a large parallel grooved pot from Layer VI, an Avonlea kitchen and kiln. Pottery was manufactured during this occupation, possibly the vessel from which the Sjovold 1 sample originated. The Sjovold 2 sample is from a knotted cord impressed vessel, associated with Layer VII, a Samantha/Avonlea household occupation. The Sjovold 3 and 4 samples are from two vessels recovered from Layer II, identified as a Moose Jaw complex summer outdoor kitchen (Dyck and Morlan 1995:198-199).

Identified faunal materials from all layers include bison, deer, snowshoe hare, ground squirrel. Bird egg shell was found in Layer II; Layer VI also contained cottontail, jackrabbit, fisher, toad, gull, and fish remains. Canid remains were found in Layer VII; a meadow vole may be of natural, rather than cultural, origin.

Evidence of food preparation and tool maintenance/manufacture occurs in all levels. No projectile points were recovered from the Moose Jaw occupation. The major activities of the Avonlea occupation were pottery manufacture and hide smoking. Evidence of hide preparation and the use of a roasting pit for shield-making or food

preparation is found in the Samantha/Avonlea occupation. There is little evidence of seasonality but Layers II and VI are believed to represent warm season occupations while Layer VII may represent a warm or cool season occupation. The inference is largely based on the assessment of the features from these layers as outdoor activity areas. Foetal bison was recovered from the interlayer VI/VII; at least part of this interlayer is associated with Layer VI (Dyck and Morlan 1995:284).

A.2. Transition Zone Sites

A.2.1 Hartley

The Hartley site, FaNp19, is located on slightly rolling, sandy terrain on the south edge of the city of Saskatoon, Saskatchewan. From the late 1980s to the mid-1990s, the site was the location of the University of Saskatchewan archaeological field school resulting in the excavation of about 100 square metres. It is a multicomponent site largely disturbed by cultivation but the material used in this study was recovered by students from an intact occupation within a willow copse. Meyer (1994) considers the cultural material recovered from this, the major occupation, to be transitional between the Avonlea and the Old Women's phases. Faunal material from the first three years of the field school was analyzed by Grant Clarke (1995) as a Master of Arts thesis research project. Clarke (1995) reports that bison dominates the faunal assemblage, representing almost 98% of the total identified specimens; 622 foetal bison bones have been found at the site. The non-bison recoveries are small but highly diverse. At least 13 species of mammals, other than bison, were represented in the faunal assemblage including dog, wolf, coyote, red and swift foxes, badger, jack rabbit and several small mammals. Seven species of birds were

found including teal, owl and grouse. Northern pike and pearly mussels were also identified.

A.2.2 Lake Midden

Lake Midden, EfNg-1, is a large single component site located in a small coulee on the east side of Last Mountain Lake, about 14 km from the town of Bulyea. Material has been collected at this site by several different avocational archaeologists and pothunters since the 1930s (Watrall 1979:24). More systematic investigations of the site occurred in the 1950s and 1960s. The University of Regina Anthropology department conducted both surface collections and excavations at the site, under the direction of Charles Watrall. The sherds made available for residue analysis are part of the University of Regina holdings of the Swanston collection and lack firm provenience.

The projectile points from the site are Late Precontact side-notched points (Watrall 1979:31). Large numbers of endscrapers, bone tools likely used in the manufacture of pottery, ice gliders and slotted knives were also recovered from the site (Walde 1994). Walde (1994:360) reports the inhabitants of Lake Midden relied heavily on bison but also utilized canids, antelope, cottontail rabbit, fox, badger, skunk, weasel (?), jackrabbit, beaver, bear and a variety of bird and fish species. Based on the presence of foetal bison remains reflecting continuous stages of growth from the onset of ossification to near full-term development, Walde (1994) suggests the site was occupied during the fall, winter and spring.

A.2.3 Lebret

The Lebret site, EeMw-26, is located on an section of the Qu'Appelle valley which

borders both Katepwa and Mission Lakes, near Lebret, Saskatchewan. Prior to impact by road construction and cottage development, mitigation excavations at the site were conducted by Brian Smith. It is a stratified, multicomponent site and sherds from three different occupations were selected for residue analysis. Lebret samples 5, 11 and 12 are from an intact Late Prairie or Plains side-notched occupation, Level 3 of Area S. Stratigraphic information is not available for Lebret samples 1 and 2, but on the basis of morphology and surface finish they are likely from this occupation as well. Lebret samples 3 and 4 are from an intact Prairie side-notched occupation, Level 2A of Area B. Lebret samples 6-10 are firmly associated with intact Avonlea occupations in Areas A and S.

The tool assemblage from these occupations indicates a variety of campsite activities occurred, mainly stone tool manufacture, fishing and hide working. Lithic recoveries include projectile points, knives, scrapers, cores and debitage. Several bone tools were recovered. Fleshers were found in all of three occupations; fish spears and needles were recovered from the Late Plains or Prairie side-notched and the Avonlea occupation.

The faunal remains from all three occupations are quite similar, consisting largely of mammals and fish but including bird and mollusc. Many of the mammal bones were very fragmented but likely bison. Other mammals remains include elk, snowshoe hare, deer, wolf, dog/coyote, beaver, badger and river otter. Fish species include northern pike, walleye, white sucker, shorthead redhorse, yellow perch, tullibee, lake whitefish and burbot. Mallard, Canada goose and the bones of unidentified small song birds were found, as well as freshwater clams. By number of identified specimens, fish remains represent

between 56.8% of the Late Prairie or Plains side-notched occupation, 27.6% of the Prairie side-notched occupation and 21.7% of the Avonlea occupation. On the basis of faunal recoveries, a spring occupation is considered to be most likely (Smith 1986; Smith and Walker 1988). No recoveries of foetal bison bone were reported.

A.2.4 Stott

The Stott site, DlMa-1, is located about 11 km west of Brandon, Manitoba where the TransCanada Highway crosses the southwest facing slope of the Assiniboine River Valley. The site includes a bison kill, campsite and burial mound. Since its discovery in 1947, studies undertaken at the site include Bird (1947), MacNeish (1954), and a series of investigations by Brandon University and Manitoba Historic Resources Branch in the late 1970s and early 1980s (Saylor 1976; Watrall 1976; Tisdale 1978; Syms *et al.* 1979; Hamilton 1981, Pokotylo and Tisdale 1982; Badertscher *et al.* 1989). A bison pound is believed to be located in Areas D and E, but excavations have been focused on the campsite. There is evidence of at least two Blackduck occupations, although the variety of projectile points, including Pelican Lake and Avonlea, and pottery indicate other groups may have also used the site (Hamilton 1981; Badertscher *et al.* 1989:323).

Faunal recoveries from different parts of the site are similar. Bison represents a large part of the identifiable faunal recoveries. Pieces identified as cloven hoofed animals or large mammal likely represent bison remains, as well. In 1982, more than 90% of the faunal remains from Area F and Upper B were likely bison (Hamilton 1981:96; Badertscher *et al.* 1989:109-114). Other species recovered include canids, beaver, rabbits/hares, deer, black bear, badger, skunk, lynx, bald eagle, fresh water clam, turtle

and snake. The presence of foetal bison bone, fish scales and molluscs in the site have prompted seasonal estimates of winter, spring and summer in descending order of probability. Unilaterally barbed bone lances or harpoon heads were found.

Potsherds selected for residue analysis are from Zones A, B, C on the east side of the highway and Zone F, on the west. The following descriptions of these zones are based on Tisdale (1978) and Hamilton (1981). Zone A is situated about two-thirds up the valley slope and is characterized by sloping land surfaces, steep-sided gullies and dense tree and shrub cover. Zone B is located on mild, undulating slopes which support a relatively thin tree cover with shrubs and introduced grasses. The area is divided into two excavation blocks, Upper B and Lower B, situated about one-third and one-quarter up the valley slope, respectively. The two blocks are separated by a vertical distance of about 7 m and a horizontal distance of 100 m. Zone C is situated on the valley bottom, which is slightly undulated due to the presence of meander scars. Disturbance processes in this zone include cultivation and intense gopher activity. Area F is situated on a terrace near the top of the valley slope and represents the last flat area before the valley crest. The bison bone bed encountered in Upper B is considered to be the remains of short-term camps, while the bone bed in Area F likely represents a long-term camp (Badertscher *et al.* 1989:280).

A.2.5 Lowton

The Lowton site, DiLv-3, is located in the Tiger Hills east of Pelican Lake, between the towns of Ninette and Baldur, in southwest Manitoba. Investigations, including surface collection and limited excavation, were conducted at the site by Chris Vickers through much of the 1940s. Avocational archaeologists continued to gather

materials from the site. Although the site has been under cultivation for several decades, sub-plough zone testing in 1992 demonstrated that intact deposits still exist at the site (Nicholson and Malainey 1995). The pottery selected for residue analysis is from the University of Manitoba holdings of the Vickers collection.

Lithics from the site include projectile points, knives, scrapers, retouched flakes and utilized flakes. A large collection of pottery has been recovered, likely representing more than one hundred individual vessels. A variety of exotic material has been recovered through surface collection. It is clear that bison was heavily exploited at the site but traces of dog, deer and rabbit bone are associated with the precontact occupation (Nicholson and Malainey 1995:97). A radiocarbon date of 510±110 BP was obtained on bone from the 1992 excavation of a hearth.

Vickers (1945) initially believed the site was occupied by Woodland peoples moving to the plains in the process of becoming nomadic bison hunter. Later, he (1946) suggested the site represented a summer horticultural village of the Hidatsa. Finally, he (1950) proposed the site served as the eastern base of people who later moved to the plains of Saskatchewan and Alberta. Reid (1972) found the Lowton pottery to be similar to that from the Middle Missouri villages, supporting Vickers' horticultural village interpretation. The evidence of horticulture at the site remains circumstantial, based on the identification of a heavy stone tool as a stone hoe. Nicholson (1990, 1994) suggests the Lowton site is similar to recoveries from Lovstrom (described below) and Johnas sites and has named this cluster of sites, the Vickers Focus. The material from these sites is considered evidence of a short-term occupation of the area by an intrusive group

following a mixed hunter-gatherer and horticultural economy (Nicholson 1990, 1994).

A.2.6 Lovstrom

The Lovstrom site, DjLx-1, is multicomponent site located 500 m north of the Souris River Valley south of Brandon, Manitoba. The results of excavations conducted at the site in the late 1980s and 1991, under the direction of Bev Nicholson, have been published (Nicholson 1986; Nicholson 1990; Nicholson 1991; Nicholson and Gibson 1990-91; Nicholson and Kuijt 1990, Nicholson and Malainey 1991; Nicholson 1994). Two components have been identified, an earlier Woodland, Blackduck and Duck Bay occupation, and a later Vickers Focus, possible horticultural occupation. The pottery made available for residue analysis was collected from the surface of a cultivated field and is similar to the Vickers Focus occupation.

The lithic recoveries from the site include Plains and Prairie side-notched projectile points, knives, scrapers and debitage. The detailed analysis of faunal remains from this site are not available, but bison dominates with small amounts of canids, rabbits or hares, small mammals and birds. The faunal recoveries from the upper occupation are highly fragmented, indicating intense processing. A reconstructed bison scapula from this occupation has been identified as a hoe (Nicholson 1990). Nicholson (1991, 1994) suggests the later inhabitants of the site supplemented their hunting and gathering economy with horticulture.

A.3 Parkland Sites

A.3.1 Bushfield West

Bushfield West, FhNa-10, was a large, prolific Late Precontact site situated on an alluvial terrace of the Saskatchewan River, south of Nipawin, Saskatchewan. The site was extensively excavated in the early 1980s by Saskatchewan Research Council archaeologists under the direction of Terry Gibson, prior to being inundated by the reservoir of the Francois Finlay hydroelectric dam in 1985. Recoveries were associated with a thin, intact paleosol found 15 cm below the ground surface which formed a well-defined continuous living floor across the site; in total, 624 square meters of the occupation were exposed (Gibson In Prep). The paleosol likely resulted from several short-term occupations of the site by one or more small groups of people in the mid-sixteenth century (Gibson In Prep:32-33).

Large parts of the site have been excavated as continuous blocks. The archaeological recoveries in many of these blocks are consistent with activities of a domestic residence, such as butchering and processing. Fishing, hunting, animal processing, hide working and clothing repair tools were recovered. A sweat lodge, several hearths and a refuse disposal area have also been identified. Over one-half of the faunal recoveries were identified as bison or beaver but the remains of a variety of mammals, birds and fish were also recovered. The remains of moose, elk, bear, canids, rabbit and several small mammals were found. Birds identified at the site include swan, goose, crane, duck, grouse, loon and grebe. Fish remains were not identified as to species (Gibson In Prep:47). The remains of a number of foetal bison and immature beaver were

found, as well as egg shell; Gibson (In Prep:7) considers the site was occupied in spring and early summer.

Nearly 10,000 sherds from at least 98 vessels were recovered. Boiling, light cooking, heavy cooking and utility vessels were identified on the basis of use wear. Samples of 19 unique Bushfield West vessels were selected for residue analysis.

A.3.2 Lockport West

Lockport West, EaLf-2, is located along the Red River north of Winnipeg in the town of Lockport. The site is situated directly across the river from the Lockport site, a multicomponent site with an established horticultural component (Buchner 1986; Buchner 1988; Flynn and Kogan 1991; Roberts 1991; Deck and Shay 1992). Testing and salvage operations were recently conducted at Lockport West to recover materials threatened by a river bank stabilization project. Material used in this study was excavated during the testing phase. Although a report on the findings is not yet available, the presence of several scapula hoes clearly establishes a horticultural component. Faunal recoveries include fish and bison but could be as diverse as those of the Lockport horticultural component. Roberts (1992) reports a dominance of fish, but the remains of bison, rabbit, beaver, canids, wolverine, badger, skunk, as well as a variety of birds and molluscs are found. Catherine Flynn (personal communication 1997) indicates the pottery from Lockport West is similar to that found in the horticultural component of the Lockport site. These vessels were probably manufactured locally and exhibit a mixture of Plains and Woodland traits similar to Red River Ware (Flynn and Kogan 1991). No radiocarbon dates are available for Lockport West, but it is likely contemporaneous with the

horticultural component at Lockport, which dates to about A.D. 1500.

A.4 Forest Sites

A.4.1 Aschkibokahn

The Aschkibokahn site, FbMb-1, is situated on Aschkibokahn Island in Lake Winnipegosis, near Duck Bay, in west-central Manitoba. Its locale falls in the mixed deciduous - coniferous forest biome (Shay 1980). Dauphin Boy Scouts and then avocational archaeologists from the Dauphin Chapter of the Manitoba Archaeological Society conducted salvage operations at the site in the early 1970s; the faunal material collected at this time was analyzed by Nicholson (1978). Professional excavations were undertaken at the site in 1976 and 1977 (Snortland-Coles 1979; Badertscher 1985). Several hearths, as well as many concentrations of ash, bone and pottery were identified.

Dense concentrations of fish remains around the hearths indicates they were used to smoke and dry fish. Hanna (1981) identified the remains of walleye, northern pike, lake whitefish, white sucker and yellow perch at Aschkibokahn. The location of the last annulus, marking with the annual cessation of growth, on almost all fish scales recovered from precontact occupations indicate they were caught in spring; fish was probably the main diet component at this time (Hanna 1981). Other faunal recoveries include moose, beaver, caribou, black bear, canids, mink skunk, snowshoe hare, eastern cottontail, deer mouse and muskrat. The only evidence of bison at the site was one, right first phalanx recovered during the Manitoba Archaeological Society salvage project in 1973 (Nicholson 1978). Several species of birds including loons, pelicans, swans, geese, ducks, heron, bald eagle and baltimore oriole were identified. Mollusc shell was also recovered.

Lithic tools from the site include projectile points, scrapers, knives and drills. Bone tools include awls, bird bone beads or tubes, beaver tooth chisels, antler knife handles, antler harpoon and bone cortex harpoon base.

Pottery at the site is dominated by Duck Bay (n=174) vessels with Blackduck (n=44) forming a minor component; one Selkirk vessel was recovered in 1977. Duck Bay vessels are most commonly found in the upper levels, from the surface to level 7 while Blackduck pottery is dominant in Levels 8 to 10 (Snortland-Coles 1979:45-48). As part of Hanna's (1982) intensive study of the Aschkibokahn pottery, latex impressions were made of the rimsherds and most other sherds bearing decoration. These sherds were avoided in an effort to minimize the levels of possible contamination. While the body sherds of the two wares are indistinguishable on the basis of surface finish, temper and manufacture (Snortland-Coles 1979:39), the sherds selected for residue analysis were mainly from the upper layers of the occupation.

A.4.2 Cabin Point

Cabin Point is one area of a large site known as Wanipigow Lake, EgKx-1, situated about 160 kilometres northeast of Winnipeg, near the town of Bissett. The large site extends over 400-500 m on the southeast part of the lake and includes a 100 m long stretch of sandy beach. Cabin Point is situated on a peninsula near the centre of the site and extends towards its eastern margin. A major excavation of the Cabin Point locale was undertaken in 1977 under the direction of Stan Saylor. A total of 67.5 m^2 were excavated to an average depth of 70 cm. While a complete analysis of the findings is not available, reports on certain aspects of the site are available (Saylor 1978; Grainger 1980; Saylor

1989; Zoltai 1989). During the excavation, a number of features were identified including hearths, refuse dumping areas, butchering areas, lithic workshops and pottery concentrations (Saylor 1978).

According to Grainger (1980), the vast majority (94.4%; 7044 of 7461) of all faunal recoveries from the Cabin Point site were classified as mammal, followed distantly by mollusc (4.1%) and fish (1.2%). Traces of bird and reptile (turtle) were also found. Much of the mammal bone could be classed only as medium to large mammal (n=4592), medium mammal (n=970) or large mammal (n=400); although, 913 elements were identified as beaver, 45 as muskrat, 20 as moose; 14 as snowshoe hare. Traces of lynx, martin, wolf, bear, river otter and red fox were present. Fish bone identifiable to species level were all sturgeon. The remains of a minimum number of 18 beaver were recovered from Cabin Point; at least three moose were found at the entire Wanipigow site area.

While several Laurel vessels were found in other parts of the site, the Cabin Point pottery is described as intermediate in style between Selkirk and Blackduck (Saylor 1978). Zoltai's (1989) paleobotantical study demonstrated the presence of carbonized goosefoot, wild rice, sarsaparilla, raspberry, wild rose, knotweed, pin cherry and hazelnut plant remains at the site.

A.4.3 Black Fox Island

The site referred to as Black Fox Island, GfPa-32, is situated on the island of the same name in the eastern portion of Lac La Biche, Alberta. The region is part of the mixed wood section of the Canadian Boreal forest region. The site was identified by the presence of archaeological materials eroding out of the sandy-clay bluff A 1982

excavation focused on the recovery of intact materials (Connor-Learn 1983); one vessel was recovered from the site. Lithic materials associated with the pot include three small, corner- and side-notched points, a black chert awl or drill, and quartzite flakes. The faunal remains from the site were well-preserved, most were extremely fragmented. Few of the 386 pieces were identifiable to species and include beaver (n=5), snowshoe hare (n=5), northern pike (n=3), and whitefish (n=3). Most bone fragments were identified as land mammal (n=154) or large land mammal (n=76). Twenty-four bones were classed as small land mammal and six others were bird bone.

APPENDIX B

ARCHAEOLOGICAL SHERD INFORMATION

Sample No.	Site No.	Site	Vessel Area	Catalogue No.	Mass (g)	Comment
VR1	Sand1a	Sanderson	rim angle	DhMs-12-76977	6.50	
VR2	Sand1b	Sanderson	body	DhMs-12-76978	5.47	
VR3	Sand7	Sanderson	rim	DhMs-12-53580	6.24	
VR4	Sand10a	Sanderson	rim	DhMs-12-78350	4.36	
VR5	Sand10b	Sanderson	shoulder	DhMs-12-78393	6.22	
VR6	Sand12	Sanderson	neck	DhMs-12-48813	6.14	excluded
VR7	Sand2	Sanderson	rim/neck	DhMs-12-76194	4.75	
VR8	Sand3	Sanderson	rim	DhMs-12-64084	3.68	
VR9	Sand4	Sanderson	rim	DhMs-12-29921	3.85	
VR10	Sand5a	Sanderson	near rim	DhMs-12-32304	3.07	
VR11	Sand5b	Sanderson	neck	DhMs-12-34373	6.49	
VR12	Sand6a	Sanderson	neck	DhMs-12-54144	10.46	
VR13	Sand6b	Sanderson	body	DhMs-12-81994	6.14	
VR14	Sand8	Sanderson	rim	DhMs-12-26199	3.45	
VR15	Sand9	Sanderson	body	DhMs-12-82021	4.18	
VR16	Sand11	Sanderson	body	DhMs-12-66387	4.95	
VR17a	Low1a	Lowton	shoulder	DiLv-3-3762	5.87	excluded
VR17b	Low1b	Lowton	shoulder	DiLv-3-3762	6.34	
VR18a	Low2a	Lowton	neck	Not Available	4.79	excluded
VR18b	Low2b	Lowton	neck	Not Available	5.43	
VR19a	Low3a	Lowton	neck	Not Available	4.63	excluded
VR19b	Low3b	Lowton	neck	Not Available	4.90	
VR20a	Low4a	Lowton	neck	DiLv-3-3765	6.29	excluded
VR20b	Low4b	Lowton	neck	DiLv-3-3765	10.50	
VR21a	Low5a	Lowton	near rim	120-267	7.37	
VR21b	Low5b	Lowton	near rim	Not Available	8.32	excluded
VR22	Low6	Lowton	body	Not Available	6.69	
VR23a	Low7a	Lowton	neck/shoulder	Not Available	5.14	
VR23b	Low7b	Lowton	neck/shoulder	Not Available	6.89	excluded
VR24a	Low8a	Lowton	body	Not Available	4.46	
VR24b	Low8b	Lowton	body	Not Available	4.70	excluded
VR25a	Low9a	Lowton	neck/shoulder	Not Available	6.36	
VR25b	Low9b	Lowton	neck/shoulder	Not Available	6.62	excluded
VR26a	Low10a	Lowton	neck	Not Available	3.95	excluded
VR26b	Low10b	Lowton	neck	Not Available	4.86	
VR27a	Low11a	Lowton	body	Not Available	3.48	excluded
VR27b	Low11b	Lowton	body	Not Available	3.67	
VR28a	Low12a	Lowton	neck/shoulder	46-120-5	8.80	
VR28b	Low12b	Lowton	neck/shoulder	46-120-5	10.80	excluded
VR29a	Low13a	Lowton	neck	DiLv-3-3767	4.42	
VR29b	Low13b	Lowton	neck	DiLv-3-3767	5.21	excluded
VR30a	Low 14a	Lowton	neck/shoulder	DiLv-3-3766	3.80	excluded
VR30b	Low 14b	Lowton	neck/shoulder	DiLv-3-3766	5.02	
VR31	Mork1	Morkin	neck	DlPk-2-6931	10.24	
VR32	Mork2	Morkin	shoulder	DlPk-2-3901	8.13	
VR33	Mork3	Morkin	body	DlPk-2-1484	9.67	
VR34	Mork4	Morkin	neck/shoulder	DlPk-2-3768	10.63	excluded
VR35	Mork5	Morkin	body	DlPk-2-2044	11.13	
VR36	Mork6	Morkin	shoulder	DlPk-2-2357	4.93	
VR37	Mork7	Morkin	shoulder	DlPk-2-4215	10.18	

Sample No.	Site No.	Site	Vessel Area	Catalogue No.	Mass (g)	Comment
VR38	Mork8	Morkin	neck	DlPk-2-4282	8.14	
VR39	Mork9	Morkin	body	DlPk-2-2356	10.25	
VR40	Mork10	Morkin	shoulder	DlPk-2-5264	9.45	
VR41	Mork11	Morkin	near rim	DlPk-2-1088	7.30	
VR42	Mork12	Morkin	near rim	DlPk-2-3161	5.87	
VR43	Mork13	Morkin	body	DlPk-2-4740	5.27	
VR44	Mork14	Morkin	neck	DlPk-2-5679	6.56	
VR45	Ross1	Ross	shoulder	DlPd-3-586	15.85	
VR46	Ross2	Ross	body	DlPd-3-383	10.08	
VR47	Ross3	Ross	body	DlPd-3-1067	8.43	
VR48	Ross4	Ross	shoulder	DlPd-3-1279	19.14	
VR49	Ross5	Ross	body	DlPd-3-1975	6.37	
VR50	Ross6	Ross	body	DlPd-3-1053	10.28	
VR51	Ross7	Ross	body	DlPd-3-205	9.24	
VR52	Ross8	Ross	body	DlPd-3-1153	23.74	
VR53	Ross9	Ross	body	DlPd-3-1322	15.86	
VR54	Ross10	Ross	body	DlPd-3-171	10.49	
VR55	Ross13	Ross	body	DlPd-3-166	17.74	
VR56	Ross11	Ross	body	DlPd-3-1687	10.61	
VR57	Ross12	Ross	body	DlPd-3-587	10.75	
VR58	Asch1	Aschkibokahn	shoulder	MDI 3095	17.55	
VR59	Asch2	Aschkibokahn	body	MDI 5974	13.47	
VR60	Asch3	Aschkibokahn	body	MDI 10860	9.66	
VR61	Asch4	Aschkibokahn	body	FbMb-1-B477	18.93	
VR62	Asch5	Aschkibokahn	neck	FbMb-1-H1263	6.39	
VR63	Asch6	Aschkibokahn	body	MDI 7885	17.37	
VR64	Asch7	Aschkibokahn	body	MDI 8282	7.48	
VR65	Asch8	Aschkibokahn	shoulder	FbMb-1-H629	15.59	
VR66	Asch9	Aschkibokahn	body	MDI 6524	8.11	
VR67	Asch10	Aschkibokahn	body	MDI 7872	7.82	
VR68	Asch11	Aschkibokahn	neck	FbMb-1-J1972	9.35	
VR69	Asch12	Aschkibokahn	body	MDI 9230	6.96	
VR70	Asch13	Aschkibokahn	neck	FbMb-1-K288	8.13	
VR71	Asch14	Aschkibokahn	body	MDI 7818	6.64	
VR72	Asch15	Aschkibokahn	neck	FbMb-1-F162	7.85	
VR73	Asch16	Aschkibokahn	near rim	FbMb-1-9855	14.08	
VR74	Asch17	Aschkibokahn	body	MDI 8930	3.85	
VR75	Asch18	Aschkibokahn	neck	MDI 2597	7.34	
VR76	LkMid1	Lake Midden	neck	EfNg-1-5 (70)	15.91	
VR77	LkMid2	Lake Midden	neck/shoulder	Not Available	10.00	
VR78	LkMid3	Lake Midden	neck	Not Available	15.34	
VR79	LkMid4	Lake Midden	rim angle	EfNg-1	8.39	
VR80	LkMid5	Lake Midden	neck	Not Available	10.84	
VR81	LkMid6	Lake Midden	neck	Not Available	13.24	
VR82	LkMid7	Lake Midden	neck	EfNg-1-5	13.00	
VR83	LkMid8	Lake Midden	near rim	Not Available	8.94	
VR84	LkMid9	Lake Midden	rim angle	Not Available	18.94	
VR85	LkMid10	Lake Midden	neck	Not Available	17.55	
VR86	LkMid11	Lake Midden	neck	Not Available	14.38	
VR87	LkMid12	Lake Midden	shoulder	Not Available	21.35	

Sample No.	Site No.	Site	Vessel Area	Catalogue No.	Mass (g)	Comment
VR88	LkMid13	Lake Midden	rim angle	Not Available	12.89	
VR89	LkMid14	Lake Midden	rim angle	EfNg-1-5 (457)	13.46	
VR90	LkMid15	Lake Midden	rim angle?	Not Available	10.40	
VR91	LkMid16	Lake Midden	neck	EfNg-1	11.48	
VR92	CabPt1	Cabin Point	neck	A50-2380	13.04	
VR93	CabPt2	Cabin Point	near rim/neck	A50-4161	18.90	
VR94	CabPt3	Cabin Point	near rim/neck	A50-3805	17.21	
VR95	CabPt4	Cabin Point	body	A50-2808	20.15	
VR96	CabPt5	Cabin Point	neck/shoulder	A50-3439	16.36	
VR97	CabPt6	Cabin Point	shoulder	A50-4828	20.22	
VR98	CabPt7	Cabin Point	neck	A50-2973	19.54	
VR99	CabPt8	Cabin Point	near rim/neck	A50-3389	8.79	
VR100	CabPt9	Cabin Point	near rim/neck	A50-2297	11.33	
VR101	CabPt10	Cabin Point	neck/shoulder	A50-5481	15.89	excluded
VR102	CabPt11	Cabin Point	neck/shoulder	A50-2141	17.28	
VR103	CabPt12	Cabin Point	neck/shoulder	A50-3043	13.18	excluded
VR104	CabPt13	Cabin Point	neck	A50-5481	12.96	
VR105	CabPt14	Cabin Point	near rim/neck	A50-2973	11.35	
VR106	CabPt15	Cabin Point	body	A50-2359	9.76	
VR107	CabPt16	Cabin Point	body	A50-1854	7.76	
VR108	CabPt17	Cabin Point	near rim/neck	A50-3439	6.12	
VR109	Stott1	Stott	body	DlMa-1-93-B7-244	7.63	
VR110	Stott2	Stott	body	DlMa-1-88-C6-346	5.52	excluded
VR111	Stott3	Stott	body	DlMa-1-85-B4-107	6.99	
VR112	Stott4	Stott	body	DlMa-1-113-44	4.80	
VR113	Stott5	Stott	body	DlMa-1-96-B3-44	7.94	
VR114	Stott6	Stott	body	DlMa-1-12-7-16	14.18	
VR115	Stott7	Stott	near shoulder	DlMa-1-41-6-1	12.13	
VR116	Stott8	Stott	body	DlMa-1-34-8-8	5.83	
VR117	Stott9	Stott	body	DlMa-1-98-B7-417	5.37	
VR118	Stott10	Stott	body	DlMa-1-80-B6-108	6.57	
VR119	Stott11	Stott	body	DlMa-1-87-D3-306	8.44	
VR120	Stott12	Stott	body	DlMa-1-21-7-5	8.65	
VR121	Stott13	Stott	near shoulder	DlMa-1-99-83	7.70	
VR122	Stott14	Stott	shoulder	DlMa-1-100-113	7.19	
VR123	Stott15	Stott	shoulder	DlMa-1-96-A7-529	8.94	
VR124	Stott16	Stott	body	DlMa-1-118-83	8.00	
VR125	Stott17	Stott	body	DlMa-1-55-7-3	13.77	excluded
VR126	Hartley1	Hartley	body	290N109E L5-179	7.98	
VR127	Hartley2	Hartley	body	293N109E L6-207	6.63	
VR128	Hartley3	Hartley	near rim	291N108E L3-43	7.70	excluded
VR129	Hartley4	Hartley	body	293N113E L4(b)-267	8.32	
VR130	Hartley5	Hartley	near rim	FaNp-19-4356	7.34	
VR131	Hartley6	Hartley	body	294N111E L3-70	8.73	
VR132	Hartley7	Hartley	near rim	295N116E L5-65(8)	4.76	
VR133	Hartley8	Hartley	neck	FaNp--19-4150	12.67	
VR134	Hartley9	Hartley	body	FaNp-19-48	14.18	
VR135	Hartley10	Hartley	body	295N111E L5-160	5.06	
VR136	HSI1	HeadSmashedIn	neck	Unit10.1-L1-D26cm	12.29	
VR137	HSI2	HeadSmashedIn	body	Unit8.9-L1-D28cm	8.18	

Sample No.	Site No.	Site	Vessel Area	Catalogue No.	Mass (g)	Comment
VR138	HSI3	HeadSmashedIn	body	Unit2.2-L1-D20cm	12.76	
VR139	HSI4	HeadSmashedIn	body	Unit10.0-L2-D33cm	10.66	
VR140	BFI1	Black Fox Island	body	GfPa-32-36	16.83	
VR141	Bush1	Bushfield West	shoulder	FhNa-10-9760	11.46	
VR142	Bush2	Bushfield West	body	FhNa-10-26218	5.44	
VR143	Bush3	Bushfield West	lower rim/neck	FhNa-10-42940	13.97	
VR144	Bush4	Bushfield West	shoulder	FhNa-10-25491	9.36	
VR145	Bush5	Bushfield West	body	FhNa-10-10081	12.48	
VR146	Bush6	Bushfield West	body	FhNa-10-24221	9.07	
VR147	Bush7	Bushfield West	near shoulder	FhNa-10-25550	3.11	
VR148	Bush8	Bushfield West	body	FhNa-10-19642	8.59	
VR149	Bush9	Bushfield West	neck	FhNa-10-42030	5.38	
VR150	Bush10	Bushfield West	shoulder	FhNa-10-20455	12.81	
VR151	Bush11	Bushfield West	neck/shoulder	FhNa-10-20391	9.43	
VR152	Bush12	Bushfield West	neck	FhNa-10-23671	12.44	
VR153	Bush13	Bushfield West	body	FhNa-10-42772	9.70	
VR154	Bush14	Bushfield West	neck	FhNa-10-19694	9.77	
VR155	Bush15	Bushfield West	neck	FhNa-10-35716	11.37	
VR156	Bush16	Bushfield West	neck	FhNa-10-32818	11.41	
VR157	Bush17	Bushfield West	neck/shoulder	FhNa-10-23977	11.40	
VR158	Bush18	Bushfield West	neck	FhNa-10-21646	8.80	
VR159	Bush19	Bushfield West	shoulder	FhNa-10-24025	7.87	
VR161	Lebret1	Lebret	body	4S 16W-4	13.75	
VR161	Lebret2	Lebret	shoulder	3S 17W-6	7.15	
VR162	Lebret3	Lebret	neck	0N 18W-11	4.50	
VR163	Lebret4	Lebret	shoulder	7S 13W-15	8.91	
VR164	Lebret5	Lebret	body	S-2-33	6.42	
VR165	Lebret6	Lebret	below shoulder	EeMw-26 1X1-2-73	8.80	
VR166	Lebret7	Lebret	body	9S 13W-10	6.55	
VR167	Lebret8	Lebret	body	S-4-48	4.36	
VR168	Lebret9	Lebret	body	A-4-21	5.52	
VR169	Lebret10	Lebret	body	A-4-20	8.77	
VR170	Lebret11	Lebret	below shoulder	S-8-9	10.92	
VR171	Lebret12	Lebret	body	S-8-10	6.96	
VR172	LngJn1	Long John	neck/shoulder	EeNj-1-80	7.12	
VR173	LngJn2	Long John	below shoulder	EeNj-1-773/7868	10.53	
VR174	LngJn3	Long John	body	EeNj-1-110	7.19	
VR175	LngJn4	Long John	neck/shoulder	EeNj-1-89	7.34	
VR176	LngJn5	Long John	neck	EeNj-1-86	4.55	
VR177	LngJn6	Long John	near rim	EeNj-1-81	5.09	
VR178	LngJn7	Long John	shoulder	EeNj-1-78	6.19	
VR179	LngJn8	Long John	shoulder	EeNj-1-85	7.75	
VR180	LngJn9	Long John	body	EeNj-1-72	7.06	
VR181	LngJn10	Long John	body	EeNj-1-78	3.98	
VR182	LngJn11	Long John	neck/shoulder	EeNj-1-75	6.54	
VR183	LngJn12	Long John	shoulder	EeNj-1-130	11.33	
VR184	LngJn13	Long John	body	EeNj-1-131	6.69	
VR185	LngJn14	Long John	shoulder	EeNj-1-87	5.20	
VR186	Sjovold1	Sjovold	body	EiNs-4-1003	12.51	
VR187	Sjovold2	Sjovold	body	EiNs-4-2407	5.54	

Sample No.	Site No.	Site	Vessel Area	Catalogue No.	Mass (g)	Comment
VR188	Sjovold3	Sjovold	body	EiNs-4-463	4.55	
VR189	Sjovold4	Sjovold	body	EiNs-4-458	4.86	
VR190	Garrett1	Garratt	body	EcNj-7-99	3.91	
VR191	Garrett2	Garratt	body	EcNj-7-1040	10.14	
VR192	Garrett3	Garratt	body	EcNj-7-236	4.13	
VR193	Garrett4	Garratt	body	EcNj-7-598	3.10	
VR194	Garrett5	Garratt	body	EcNj-7-1029	10.83	
VR195	Garrett6	Garratt	body	EcNj-7-226	6.33	
VR196	Garrett7	Garratt	body	EcNj-7-593	4.37	
VR197	Garrett8	Garratt	body	EcNj-7-361	9.82	
VR198	Garrett9	Garratt	body	EcNj-7-361	6.46	
VR199	Garrett10	Garratt	body	EcNj-7-598	3.85	
VR200	Garrett11	Garratt	below shoulder	EcNj-7-819	5.81	
VR201	Garrett12	Garratt	body	EcNj-7-361	6.14	
VR202	Garrett13	Garratt	body	EcNj-7-566	7.82	
VR203	Lckprt1	Lockport West	rim and neck	EaLf-2-3-3-8	7.19	
VR204	Lckprt2	Lockport West	neck	EaLf-2-3-3-6	9.92	
VR205	Lckprt3	Lockport West	rim and neck	EaLf-2-3-3-7	7.01	
VR206	Lckprt4	Lockport West	body	EaLf-2-3-3-62	5.17	
VR207	Lckprt5	Lockport West	body	EaLf-2-2-6-8	7.42	
VR208	Lckprt6	Lockport West	shoulder	EaLf-2-3-3-54	6.50	
VR209	Lckprt7	Lockport West	shoulder	EaLf-2-2-S-1	11.62	
VR210	Lckprt8	Lockport West	rim and neck	EaLf-2-3-3-9	11.54	
VR211	Lvstrm1	Lovstrom	below shoulder	DjLx-1-S-1-395	7.66	
VR212	Lvstrm2	Lovstrom	rim	DjLx-1-S-1-394	6.40	
VR213	Lvstrm3	Lovstrom	neck	DjLx-1-S-1-391	4.36	

Appendix C: Plant Samples in the Modern Reference Collection.

Table C-1. Collected samples of food plants used in the spring (May-early June).

FAMILY	*GENUS SPECIES*	COMMON NAME	PART	LOCATION
ARALIACEAE	*Aralia nudicaulis*	sarsaparilla	root,greens	Delta Marsh
COMPOSITAE	*Helianthus tuberosus*	Jerusalem artichoke	root	Delta Marsh
CYPERACEAE	*Scirpus spp.*	bulrush	root,greens	Delta Marsh
GRAMINEAE	*Phragmites australis*	giant reed	root	Delta Marsh
LILIACEAE	*Allium spp.*	wild onion	root,greens	Shilo
LILIACEAE	*Smilacina spp.*	false Solomon's seal	greens	Delta Marsh
LILIACEAE	*Smilacina spp.*	false Solomon's seal	greens	Lauder
ONAGRACEAE	*Epilobium angustifolium*	fireweed	greens	Whiteshell
POLYPODIACEAE	*Matteuccia struthiopteris*	ostrich-fern	root	Delta Marsh
TYPHACEAE	*Typha latifolia*	cat-tail	root,greens	Delta Marsh
TYPHACEAE	*Typha latifolia*	cat-tail	root,greens	Bird's Hill
URTICACEAE	*Urtica dioica*	stinging nettle	greens	Delta Marsh
VIOLACEAE	*Viola spp.*	violet	greens	Delta Marsh

Table C-2. Collected samples of food plants used in the summer (early June-early August).

FAMILY	*GENUS SPECIES*	Common Name	PART	LOCATION
CARYOPHYLLACEAE	*Stellaria spp.*	chickweed	greens	Lauder
CHENOPODIACEAE	*Chenopodium spp.*	goosefoot	greens, seeds	Lauder
CHENOPODIACEAE	*Chenopodium spp.*	goosefoot	greens, seeds	Duck Bay
COMPOSITAE	*Solidago spp.*	goldenrod	greens	Turtle Mountain
COMPOSITAE	*Solidago spp.*	goldenrod	greens	Duck Bay
COMPOSITAE	*Solidago spp.*	goldenrod	greens	Lac Du Bonnett
CYPERACEAE	*Scirpus spp.*	bulrush	greens, flowers	Lac Du Bonnett
ERICACEAE	*Vaccinium spp.*	blueberry	berries	Lac Du Bonnett
HIPPURIDACEAE	*Hippuris vulgaris*	mare's-tail	greens	Lauder

JUNCAGINACEAE	*Triglochin maritima*	arrow-grass	seeds	Maple Lake
JUNCAGINACEAE	*Triglochin maritima*	arrow-grass	seeds	Duck Bay
JUNCAGINACEAE	*Triglochin maritima*	arrow-grass	seeds	Lac Du Bonnett
LEGUMINOSAE	*Psoralea esculenta*	breadroot	root	Spruce Woods
LILIACEAE	*Lilium philadelphicum*	lily	root	Lauder
ONAGRACEAE	*Epilobium angustifolium*	fireweed	roots, greens	Swan River
POLYGONACEAE	*Rumex spp.*	dock	greens, seeds	Lac Du Bonnett
ROSACEAE	*Rosa spp.*	rose	flowers,berries	Lauder
ROSACEAE	*Rosa spp.*	rose	flowers,berries	Lac Du Bonnett
ROSACEAE	*Amelanchier alnifolia*	saskatoon	berries	Lac Du Bonnett
ROSACEAE	*Amelanchier alnifolia*	saskatoon	berries	Wood Mountain
ROSACEAE	*Amelanchier alnifolia*	saskatoon	berries	Swan River
TYPHACEAE	*Typha latifolia*	cat-tail	all	Lac Du Bonnett
TYPHACEAE	*Typha latifolia*	cat-tail	all	Lauder
UMBELLIFERAE	*Heracleum lanatum*	cow-parsnip	greens, roots	Turtle Mountain

Table C-3. Collected samples of food plants used in the late summer.

FAMILY	*GENUS SPECIES*	COMMON NAME	PART	LOCATION
ALISMATACEAE	*Sagittaria spp.*	arrowhead	roots	Pinawa
ARACEAE	*Calla palustris*	wild calla	roots	Pinawa
BETULACEAE	*Corylus spp.*	hazelnut	nuts	Beausejour
CHENOPODIACEAE	*Chenopodium spp.*	goosefoot	seeds	Lauder
COMPOSITAE	*Helianthus tuberosus*	Jerusalem artichoke	roots	Duck Bay
COMPOSITAE	*Iva spp.*	marsh-elder	seeds	Lockport
CORNACEAE	*Cornus spp.*	dogwood	berries	Swan River
ERICACEAE	*Arctostaphylos uva-ursi*	bearberry	berries	Bird's Hill
GRAMINEAE	*Phragmites australis*	giant reed	roots	Duck Bay
LABIATAE	*Lycopus spp.*	water-horehound	roots	Duck Bay
LABIATAE	*Stachys palustris*	marsh hedge nettle	roots	Duck Bay

LEGUMINOSAE	*Lathyrus spp.*	vetchling	seeds	Swan River
LILIACEAE	*Smilacina spp.*	false Solomon's seal	roots	Swan River
LILIACEAE	*Smilacina spp.*	false Solomon's seal	roots	Spruce Woods
POLYGONACEAE	*Polygonum spp.*	knotweed	seeds	Spruce Woods
POLYGONACEAE	*Rumex spp.*	dock	seeds	Swan River
ROSACEAE	*Crataegus spp.*	hawthorn	hips	Wood Mountain
ROSACEAE	*Prunus pensylvanica*	pin cherries	berries	Lac Du Bonnett
ROSACEAE	*Prunus pensylvanica*	pin cherries	berries	Wood Mountain
ROSACEAE	*Prunus virginianus*	choke cherry	berries	Spruce Woods
ROSACEAE	*Prunus virginianus.*	choke cherry	berries	Wood Mountain
ROSACEAE	*Prunus virginianus*	choke cherry	berries	Beausejour
ROSACEAE	*Prunus virginianus*	choke cherry	berries	Swan River
ROSACEAE	*Rosa spp.*	rose	hips	Bird's Hill
ROSACEAE	*Rosa spp.*	rose	hips	Pinawa
ROSACEAE	*Rosa spp.*	rose	hips	Wood Mountain
ROSACEAE	*Rosa spp.*	rose	hips	Swan River
SAXIFRAGACEAE	*Ribes oxyacanthoides*	gooseberry	berries	Swan River
SAXIFRAGACEAE	*Ribes oxyacanthoides*	gooseberry	berries	Wood Mountain
SPARGANIACEAE	*Sparganium spp.*	bur-reed	roots	Pinawa
SPARGANIACEAE	*Sparganium spp.*	bur-reed	roots	Lauder
UMBELLIFERRAE	*Heracleum lanatum*	cow-parsnip	roots	Swan River
UMBELLIFERRAE	*Sium suave*	water-parsnip	roots	Duck Bay
UMBELLIFERRAE	*Sium suave*	water parsnip	roots	Swan River
UMBELLIFERRAE	*Sium suave*	water parsnip	roots	Lac Du Bonnett
	Armillaria spp.	edible mushroom	all	Bird's Hill
	Leccinum spp.	edible mushroom	all	Bird's Hill

Primary source:
Shay, C. Thomas (1980) Food Plants of Manitoba. In Directions in Manitoba Prehistory: Papers in Honour of Chris Vickers, edited by Leo Pettipas, pp. 233-290. Association of Manitoba Archaeologists and Manitoba Archaeological Society, Winnipeg.

APPENDIX D

Table of fatty acid composition of modern reference in groups produced by hierarchical cluster analysis.

CLUSTER I - Bear Fat and Cow Bone marrow

No.	Name	Type	C12:0	C14:0	C14:1	C15:0	C16:0	C16:1w9	C16:1	C16:2	C17:0
M1	bear	fat	0.01	1.12	0.06	0.17	18.16	0.24	1.96	0.36	0.35
M135	cow	marrow	0.42	3.77	0.89	0.18	21.65	4.64	0.26	0.00	0.51
		Mean	0.22	2.44	0.47	0.18	19.90	2.44	1.11	0.18	0.43
		Std. Dev.	0.29	1.87	0.59	0.01	2.47	3.11	1.20	0.26	0.11
		Nu	2	2	2	2	2	2	2	2	2

No.	Name	Type	C17:1	C18:0	C18:1	C18:1w11	C18:2	C19:0	C18:3w3	C20:0	C20:1
M1	bear	fat	0.28	5.89	59.08	1.49	8.54	0.05	0.89	0.23	0.82
M135	cow	marrow	0.00	8.22	50.25	2.73	5.47	0.00	0.48	0.06	0.25
		Mean	0.14	7.06	54.66	2.11	7.01	0.02	0.68	0.14	0.53
		Std. Dev.	0.19	1.65	6.24	0.88	2.17	0.04	0.29	0.12	0.40
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	C20:2	C20:3w6	C20:4w6	C20:3w3	C22:0	C22:1	C24:1
M1	bear	fat	0.00	0.06	0.04	0.00	0.05	0.07	0.10
M135	cow	marrow	0.11	0.05	0.05	0.03	0.00	0.00	0.00
		Mean	0.05	0.05	0.04	0.02	0.02	0.03	0.05
		Std. Dev.	0.08	0.00	0.00	0.02	0.03	0.05	0.07
		Count	2	2	2	2	2	2	2

CLUSTER II - LARGE HERBIVORE MEAT

No.	Name	Type	C12:0	C14:0	C14:1	C15:0	C16:0	C16:1w9	C16:1	C16:2	C17:0
M128	bison	meat	0.12	2.64	0.18	0.55	18.80	2.23	2.67	0.37	1.20
M129	deer	meat	0.00	1.41	0.18	0.31	19.98	1.42	0.40	0.41	1.07
		Mean	0.06	2.03	0.18	0.43	19.39	1.83	1.54	0.39	1.14
		Std. Dev.	0.08	0.87	0.00	0.17	0.83	0.57	1.61	0.03	0.10
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	C17:1	C18:0	C18:1	C18:2	C19:0	C18:3	C20:0	C20:1	C20:2
M128	bison	meat	0.61	22.34	38.07	6.50	0.11	0.60	0.23	0.19	0.00
M129	deer	meat	0.40	18.35	33.51	11.37	0.00	4.63	0.19	0.12	0.16
		Mean	0.51	20.35	35.79	8.93	0.05	2.61	0.21	0.16	0.08
		Std. Dev.	0.15	2.82	3.23	3.44	0.08	2.85	0.03	0.05	0.11
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	20:3w6	C20:4w6	C20:3w3	C20:5	C22:5	C24:0
M128	bison	meat	0.15	1.65	0.23	0.00	0.33	0.00
M129	deer	meat	0.37	3.51	0.10	1.75	0.00	0.21
		Mean	0.26	2.58	0.16	0.88	0.17	0.11
		Std. Dev.	0.16	1.31	0.09	1.24	0.23	0.15
		Count	2	2	2	2	2	2

Cluster III - Fish

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1
M130	catfish	fish	1.42	0.16	2.29	0.07	0.72	0.00	16.00	7.55	0.57
M29	pickerel	fish	0.02	0.00	1.40	0.08	0.40	0.00	17.12	0.85	6.78
M31	perch	fish	0.03	0.00	1.02	0.07	0.30	0.46	18.38	0.81	6.53
M33	smtrout	fish	0.44	0.02	3.39	0.09	0.31	0.05	12.77	0.48	6.47
		Mean	0.48	0.04	2.03	0.08	0.43	0.13	16.07	2.42	5.09
		Std Dev	0.66	0.07	1.05	0.01	0.20	0.22	2.40	3.42	3.02
		Count	4	4	4	4	4	4	4	4	4

No.	Name	Type	16:2	17:0	17:1	18:0	18:1	18:1w11	18:2	18:3w6	19:0
M130	catfish	fish	1.09	0.94	1.20	4.52	13.45	6.83	3.45	0.13	0.14
M29	pickerel	fish	0.41	0.58	0.77	3.67	12.99	4.12	2.02	0.21	0.13
M31	perch	fish	0.21	0.49	0.69	3.70	10.05	5.27	2.09	0.18	0.09
M33	smtrout	fish	0.26	0.35	0.43	3.58	17.12	3.30	4.07	0.23	0.06
		Mean	0.49	0.59	0.77	3.87	13.40	4.88	2.91	0.19	0.11
		Std Dev	0.41	0.25	0.32	0.44	2.90	1.53	1.02	0.04	0.04
		Count	4	4	4	4	4	4	4	4	4

No.	Name	Type	18:3	18:4	20:0	20:1	20:2	20:3w6	20:4w6	20:3w3	20:4w3
M130	catfish	fish	6.39	1.33	0.24	0.79	0.89	0.62	6.01	0.56	0.00
M29	pickerel	fish	4.19	1.19	0.18	0.54	0.33	0.22	3.64	0.72	1.51
M31	perch	fish	3.00	0.67	0.12	0.35	0.22	0.21	5.39	0.39	0.90
M33	smtrout	fish	3.98	3.18	0.23	0.81	1.20	0.42	3.12	1.03	3.93
		Mean	4.39	1.59	0.19	0.62	0.66	0.37	4.54	0.67	1.58
		Std Dev	1.43	1.10	0.05	0.22	0.46	0.19	1.38	0.27	1.68
		Count	4	4	4	4	4	4	4	4	4

No.	Name	Type	20:5	22:0	22:1	22:2	22:3	22:4	22:5	22:6
M130	catfish	fish	9.30	0.10	0.00	0.10	1.36	0.00	3.50	8.30
M29	pickerel	fish	8.69	0.03	0.07	0.05	1.59	1.64	3.03	20.86
M31	perch	fish	8.08	0.02	0.05	0.02	1.57	1.73	3.15	23.72
M33	smtrout	fish	5.56	0.00	0.00	0.33	1.54	2.47	4.12	15.10
		Mean	7.91	0.04	0.03	0.12	1.51	1.46	3.45	17.00
		Std Dev	1.64	0.05	0.04	0.14	0.11	1.04	0.49	6.81
		Count	4	4	4	4	4	4	4	4

Cluster IV - Fish

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1
M30	whitefish	fish	0.15	0.03	3.19	0.10	0.40	0.00	13.86	0.00	13.96
M32	smgoldeye	fish	0.03	0.03	2.51	0.17	0.27	0.16	14.34	0.97	9.43
		Mean	0.09	0.03	2.85	0.14	0.34	0.08	14.10	0.49	11.69
		Std Dev	0.09	0.01	0.48	0.05	0.09	0.11	0.34	0.69	3.20
		Count	2	2	2	2	2	2	2	2	2

		Type	16:2	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0
M30	whitefish	fish	0.29	0.56	0.59	2.95	23.38	5.20	2.26	0.27	0.07
M32	smgoldeye	fish	0.20	0.31	0.83	2.60	31.17	4.17	5.81	0.25	0.05
		Mean	0.25	0.43	0.71	2.78	27.27	4.69	4.04	0.26	0.06
		Std Dev	0.06	0.18	0.16	0.25	5.51	0.73	2.51	0.02	0.01
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	18:3	18:4	20:0	20:1	20:2	20:3w6	20:4w6	20:3w3	20:4w3
M30	whitefish	fish	1.98	1.57	0.15	1.22	0.45	0.39	1.95	0.33	0.97
M32	smgoldeye	fish	5.68	1.71	0.13	0.28	0.23	0.31	2.23	0.36	2.96
		Mean	3.83	1.64	0.14	0.75	0.34	0.35	2.09	0.35	1.97
		Std Dev	2.61	0.10	0.02	0.67	0.16	0.06	0.20	0.35	1.97
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	20:5	22:0	22:1	22:2	22:3	22:4	22:5	22:6
M30	whitefish	fish	9.38	0.02	0.23	0.15	0.54	0.69	3.52	9.18
M32	smgoldeye	fish	6.16	0.00	0.00	0.09	0.42	0.12	2.78	3.24
		Mean	7.77	0.01	0.12	0.12	0.48	0.41	3.15	6.21
		Std Dev	2.28	0.01	0.16	0.04	0.85	0.40	0.52	4.20
		Count	2	2	2	2	2	2	2	2

CLUSTER V - CHERRY AND NUT

No.	Name	Type	12:0	14:0	15:0	16:0	16:1w9	16:1	16:2	17:0	17:1
M4	chokecherry	berry	0.00	0.16	0.05	4.67	0.05	0.32	0.05	0.13	0.11
M21	hazelnut	nut	0.00	0.03	0.03	3.87	0.06	0.11	0.00	0.07	0.09
M82	chokecherry	berry	0.02	0.05	0.02	4.23	0.00	0.17	0.00	0.08	0.12
M85	pin cherry	berry	0.00	0.05	0.03	2.30	0.00	0.28	0.00	0.07	0.13
M91	chokecherry	berry	0.00	0.04	0.03	3.56	0.00	0.11	0.00	0.09	0.11
M113	chokecherry	berry	0.02	0.04	0.02	3.75	0.00	0.04	0.00	0.09	0.13
		Mean	0.01	0.06	0.03	3.73	0.02	0.17	0.01	0.09	0.12
		Std Dev	0.01	0.05	0.01	0.80	0.03	0.11	0.02	0.02	0.01
		Count	6	6	6	6	6	6	6	6	6

No.	Name	Type	18:0	18:1w9	18:1w11	18:2	18:3	20:0	20:1	20:2	22:0
M4	chokecherry	berry	3.04	57.24	1.32	31.02	0.94	0.19	0.19	0.00	0.29
M21	hazelnut	nut	1.46	65.23	0.00	27.62	0.53	0.24	0.36	0.00	0.08
M82	chokecherry	berry	1.61	49.49	0.00	40.93	1.13	0.26	0.16	0.02	1.30
M85	pin cherry	berry	0.94	48.37	0.00	46.50	0.87	0.15	0.20	0.02	0.00
M91	chokecherry	berry	1.87	52.52	0.00	39.60	1.08	0.27	0.20	0.04	0.21
M113	chokecherry	berry	1.47	51.14	0.00	41.44	1.05	0.24	0.18	0.03	0.00
		Mean	1.73	54.00	0.22	37.85	0.93	0.22	0.22	0.02	0.31
		Std Dev	0.71	6.31	0.54	7.09	0.22	0.05	0.07	0.02	0.50
		Count	6	6	6	6	6	6	6	6	6

No.	Name	Type	22:1	24:0	24:1
M4	chokecherry	berry	0.00	0.30	0.00
M21	hazelnut	nut	0.00	0.17	0.03
M82	chokecherry	berry	0.00	0.42	0.00
M85	pin cherry	berry	0.00	0.05	0.05
M91	chokecherry	berry	0.00	0.27	0.00
M113	chokecherry	berry	0.18	0.18	0.01
		Mean	0.03	0.23	0.01
		Std Dev	0.07	0.13	0.02
		Count	6	6	6

CLUSTER VI - MIXED

No.	Name	Type	12:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1	16:2
M14	acorn	nut	0.05	0.26	0.00	0.15	0.00	9.13	0.21	0.16	0.00
M16	knotweed	seed	0.13	0.51	0.21	0.24	0.00	11.56	0.58	0.23	0.00
M48	*Armillaria*	whole	0.70	0.28	0.06	0.30	0.00	10.01	0.00	6.61	0.32
M49	*Leccinum*	whole	0.00	0.33	0.00	1.85	0.00	12.85	0.64	1.16	0.59
M73	*Rumex*	seeds	0.08	0.21	0.00	0.16	0.00	11.03	0.38	0.28	0.07
M123	Rumex	seed	0.28	0.77	0.00	0.18	0.22	14.22	0.22	0.00	0.16
M126	Rumex	seed	0.00	0.15	0.00	0.15	0.00	10.21	0.86	0.00	0.31
M133	beaver	meat	0.08	0.83	0.07	0.17	0.00	17.43	4.46	0.11	0.10
		Mean	0.16	0.42	0.04	0.40	0.03	12.06	0.92	1.07	0.19
		Std Dev	0.24	0.26	0.07	0.59	0.08	2.72	1.46	2.27	0.20
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3
M14	acorn	nut	0.30	0.27	1.82	36.91	0.83	41.10	0.00	0.03	5.79
M16	knotweed	seed	0.34	0.00	1.61	34.14	1.43	36.70	0.00	0.00	5.88
M48	*Armillaria*	whole	0.03	0.06	2.31	40.49	5.00	30.71	0.00	0.00	0.00
M49	*Leccinum*	whole	0.11	0.28	0.90	39.76	0.00	40.65	0.00	0.00	0.14
M73	*Rumex*	seeds	0.17	0.16	1.74	26.83	2.56	44.05	0.00	0.00	2.64
M123	Rumex	seed	0.30	0.00	2.32	28.85	0.00	35.04	0.00	0.00	5.44
M126	Rumex	seed	0.16	0.00	1.74	27.22	0.00	34.30	0.00	0.00	6.49
M133	beaver	meat	0.26	0.33	6.41	35.11	3.21	24.07	0.10	0.07	2.87
		Mean	0.21	0.14	2.36	33.66	1.63	35.83	0.01	0.01	3.66
		Std Dev	0.11	0.14	1.70	5.45	1.83	6.40	0.04	0.03	2.62
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	18:4	20:0	20:1	20:2	20:3w6	20:4w6	20:5	22:0	22:1
M14	acorn	nut	0.00	0.59	0.67	0.00	0.00	0.00	0.00	0.74	0.00
M16	knotweed	seed	0.00	0.70	1.41	0.43	0.00	0.00	0.00	1.34	0.92
M48	*Armillaria*	whole	0.00	0.30	0.30	0.05	0.00	0.00	0.00	0.26	0.11
M49	*Leccinum*	whole	0.00	0.14	0.06	0.13	0.00	0.00	0.00	0.21	0.00
M73	*Rumex*	seeds	0.00	2.34	0.61	0.25	0.00	0.00	0.00	1.11	1.77
M123	Rumex	seed	0.00	2.17	0.85	0.69	0.00	0.00	0.00	2.47	0.00
M126	Rumex	seed	0.00	1.20	1.25	0.29	0.00	0.00	0.00	2.63	2.78
M133	beaver	meat	0.43	0.24	0.53	0.23	0.11	0.78	1.18	0.00	0.00
		Mean	0.05	0.96	0.71	0.26	0.01	0.10	0.15	1.10	0.70
		Std Dev	0.15	0.87	0.45	0.22	0.04	0.27	0.42	1.01	1.06
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	22:2	22:3	22:5	24:0	22:6	24:1
M14	acorn	nut	0.00	0.00	0.00	0.85	0.00	0.11
M16	knotweed	seed	0.00	0.00	0.00	1.22	0.00	0.43
M48	*Armillaria*	whole	0.07	0.00	0.00	0.57	0.00	1.47
M49	*Leccinum*	whole	0.00	0.00	0.00	0.18	0.00	0.00
M73	*Rumex*	seeds	0.10	0.00	0.00	2.14	0.00	1.33
M123	Rumex	seed	0.00	0.00	0.00	4.72	0.00	1.10
M126	Rumex	seed	0.00	0.00	0.00	9.53	0.00	0.74
M133	beaver	meat	0.00	0.23	0.40	0.00	0.17	0.00
		Mean	0.02	0.03	0.05	2.40	0.02	0.65
		Std Dev	0.04	0.08	0.14	3.25	0.06	0.60
		Count	8	8	8	8	8	8

CLUSTER VII - SEEDS AND BERRIES

No.	Name	Part	12:0	13:0	14:0	15:0	16:0	16:1w9	16:1	17:0	17:1
M77	flint corn	kernal	0.00	0.00	0.03	0.00	10.49	0.00	0.03	0.09	0.00
M79	sweet corn	kernal	0.00	0.00	0.03	0.00	10.72	0.00	0.04	0.08	0.00
M80	sunflower	seed	0.00	0.00	0.05	0.02	5.72	0.00	0.02	0.09	0.00
M81	wint. squash	seed	0.00	0.00	0.12	0.02	10.15	0.00	0.11	0.15	0.09
M95	saskatoon	berry	0.07	0.00	0.11	0.06	7.45	0.29	0.38	0.21	0.10
M98	saskatoon	berry	0.05	0.00	0.10	0.06	7.77	0.27	0.47	0.19	0.00
M118	bulrush	seed	0.00	0.10	0.08	0.14	5.88	0.00	0.20	0.20	0.16
M20	hawthorn	berry	0.08	0.00	0.09	0.05	7.16	0.11	0.11	0.19	0.08
M88	pin cherry	berry	0.00	0.00	0.03	0.02	1.99	0.04	0.17	0.05	0.14
		Mean	0.02	0.01	0.07	0.04	7.48	0.08	0.17	0.14	0.06
		Std Dev	0.03	0.03	0.04	0.04	2.80	0.12	0.16	0.06	0.07
		Count	9	9	9	9	9	9	9	9	9

No.	Name	Part	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3	18:4	20:0
M77	flint corn	kernal	2.38	31.81	0.00	52.58	0.00	0.00	1.19	0.00	0.57
M79	sweet corn	kernal	1.95	32.51	0.00	52.22	0.00	0.00	1.13	0.00	0.50
M80	sunflower	seed	4.46	31.60	0.00	55.71	0.00	0.00	0.13	0.00	0.41
M81	wint. squash	seed	7.41	28.97	0.00	51.81	0.00	0.00	0.18	0.00	0.53
M95	saskatoon	berry	2.04	24.07	0.00	52.60	0.02	0.00	3.00	0.00	2.92
M98	saskatoon	berry	1.79	26.79	0.00	52.12	0.00	0.00	2.27	0.00	2.46
M118	bulrush	seed	0.54	25.01	0.00	60.40	0.09	0.00	3.16	0.00	0.71
M20	hawthorn	berry	1.96	22.94	0.52	56.87	0.00	0.20	2.13	0.18	1.63
M88	pin cherry	berry	0.71	37.82	0.00	57.88	0.00	0.00	0.43	0.00	0.10
		Mean	2.58	29.06	0.06	54.69	0.01	0.02	1.51	0.02	1.09
		Std Dev	2.13	4.83	0.17	3.13	0.03	0.07	1.17	0.06	1.00
		Count	9	9	9	9	9	9	9	9	9

No.	Name	Part	20:1	20:2	22:0	22:1	22:3	24:0	24:1
M77	flint corn	kernal	0.31	0.03	0.17	0.00	0.00	0.24	0.08
M79	sweet corn	kernal	0.32	0.04	0.18	0.00	0.00	0.21	0.07
M80	sunflower	seed	0.21	0.03	1.24	0.00	0.00	0.30	0.03
M81	wint. squash	seed	0.08	0.00	0.14	0.00	0.00	0.12	0.11
M95	saskatoon	berry	0.97	0.13	4.05	0.00	0.00	1.47	0.07
M98	saskatoon	berry	1.09	0.14	3.08	0.00	0.00	1.13	0.23
M118	bulrush	seed	0.49	0.09	1.52	0.07	0.00	1.05	0.12
M20	hawthorn	berry	0.69	0.09	0.65	0.00	3.22	1.00	0.05
M88	pin cherry	berry	0.16	0.03	0.38	0.00	0.00	0.03	0.00
		Mean	0.48	0.06	1.27	0.01	0.36	0.62	0.09
		Std Dev	0.36	0.05	1.41	0.02	1.07	0.54	0.07
		Count	9	9	9	9	9	9	9

CLUSTER VIII - ROOTS

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1
M8	false solomon's	root	0.13	0.13	0.32	0.05	0.74	0.09	24.05	0.46	1.77
M22	Jer. artichoke	root	2.33	0.38	0.40	0.41	2.42	0.00	15.94	0.00	0.64
M23	prairie turnip	root	0.00	0.00	0.00	0.00	0.00	0.00	18.37	0.00	0.00
M24	cowparsnip	root	0.34	0.14	0.53	0.00	1.09	0.00	20.62	0.00	0.30
M27	cowparsnip	root	0.35	0.10	0.63	0.16	1.30	0.59	16.38	0.00	0.28
M39	wild onion	root	0.58	0.00	0.67	0.00	0.44	0.31	19.75	2.37	0.53
M105	tiger lily	root	0.00	0.00	0.16	0.00	0.12	0.00	20.33	0.51	0.88
M107	wild calla	root	0.00	0.03	0.31	0.00	0.34	0.00	25.10	1.84	0.69
M104	vetchling pods	pods	0.07	0.00	0.49	0.00	0.46	0.28	14.69	1.62	1.09
M112	waterparsnip	root	0.53	0.32	0.61	0.00	0.69	0.00	22.08	0.00	0.00
M124	false solomon's	root	0.33	0.00	0.53	0.00	0.64	0.00	22.43	0.18	0.63
		Mean	0.43	0.10	0.42	0.06	0.75	0.12	19.98	0.64	0.62
		Std Dev	0.67	0.14	0.21	0.13	0.68	0.20	3.37	0.88	0.51
		Count	11	11	11	11	11	11	11	11	11

No.	Name	Type	16:2	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0
M8	false solomon's	root	0.00	0.66	0.00	2.56	5.89	0.81	42.61	0.00	0.19
M22	Jer. artichoke	root	1.20	0.84	0.00	1.42	2.92	1.42	50.78	0.00	0.00
M23	prairie turnip	root	0.00	0.62	0.00	3.83	4.26	0.00	48.12	0.28	0.00
M24	cowparsnip	root	0.00	0.57	0.00	1.74	4.00	1.98	56.51	0.00	0.00
M27	cowparsnip	root	0.08	0.78	0.13	1.93	2.42	1.37	56.21	0.00	0.07
M39	wild onion	root	0.17	0.51	0.23	4.03	10.00	1.28	40.04	0.61	0.00
M105	tiger lily	root	0.28	0.57	0.22	2.46	3.15	4.61	45.26	0.00	0.07
M107	wild calla	root	1.69	0.17	0.00	1.19	5.69	3.75	42.46	0.00	0.00
M104	vetchling pods	pods	0.00	0.42	0.00	2.23	9.48	0.00	54.09	0.10	0.00
M112	waterparsnip	root	0.00	0.56	0.00	4.05	3.76	1.70	47.82	0.00	0.00
M124	false solomons	root	0.00	0.58	0.00	3.01	1.92	1.68	52.21	0.00	0.00
		Mean	0.31	0.57	0.05	2.59	4.86	1.69	48.74	0.09	0.03
		Std Dev	0.58	0.18	0.09	1.03	2.70	1.40	5.72	0.19	0.06
		Count	11	11	11	11	11	11	11	11	11

No.	Name	Type	18:3	20:0	20:1	20:2	22:0	22:1	22:2	24:0	24:1
M8	false solomon's	root	7.22	1.28	1.74	0.00	3.74	0.91	0.00	4.55	0.07
M22	Jer. artichoke	root	9.18	1.21	0.57	0.48	2.60	0.40	0.00	2.43	2.03
M23	prairie turnip	root	8.81	2.03	0.00	0.00	6.04	0.00	0.00	7.62	0.00
M24	cowparsnip	root	6.03	1.26	0.75	0.54	1.80	0.00	0.00	1.81	0.00
M27	cowparsnip	root	6.24	2.56	1.08	0.38	2.38	0.00	0.00	3.55	1.01
M39	wild onion	root	5.33	2.83	0.58	1.05	3.56	0.00	0.00	3.54	1.59
M105	tiger lily	root	3.08	1.38	0.48	0.32	3.46	0.00	0.06	12.62	0.00
M107	wild calla	root	12.85	0.30	0.55	0.50	0.97	0.28	0.12	0.90	0.28
M104	vetchling pods	pods	9.54	1.07	0.59	0.26	1.34	0.00	0.00	2.18	0.00
M112	waterparsnip	root	6.55	3.00	0.97	0.79	3.91	0.00	0.00	2.66	0.00
M124	false solomons	root	4.81	1.99	5.20	0.00	1.47	0.48	0.00	1.46	0.43
		Mean	7.24	1.72	1.14	0.39	2.84	0.19	0.02	3.94	0.49
		Std Dev	2.70	0.83	1.42	0.33	1.49	0.30	0.04	3.41	0.73
		Count	11	11	11	11	11	11	11	11	11

CLUSTER IX - SEEDS

No.	Name	Type	12:0	13:0	14:0	15:0	br16:0	16:0	16:1w9	16:1	16:2
M70	marsh-elder	seed	0.95	0.44	0.42	0.14	0.00	9.01	0.81	0.51	0.00
M102	arrowgrass	seed	0.14	0.00	0.20	0.16	0.34	7.44	0.00	1.50	0.00
M116	arrowgrass	seed	0.06	0.01	0.11	0.07	0.08	6.11	0.75	0.00	0.04
		Mean	0.38	0.15	0.24	0.12	0.14	7.52	0.52	0.67	0.01
		Std Dev	0.50	0.25	0.15	0.05	0.18	1.46	0.45	0.76	0.02
		Count	3	3	3	3	3	3	3	3	3

No.	Name	Type	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3
M70	marsh-elder	seed	0.29	0.63	6.29	4.86	1.09	59.70	0.33	0.12	5.12
M102	arrowgrass	seed	0.43	0.08	2.24	10.58	0.40	62.06	0.00	0.40	8.13
M116	arrowgrass	seed	0.21	0.06	2.12	13.14	0.00	70.66	0.00	0.02	3.20
		Mean	0.31	0.26	3.55	9.52	0.50	64.14	0.11	0.18	5.49
		Std Dev	0.11	0.32	2.37	4.24	0.55	5.77	0.19	0.20	2.48
		Count	3	3	3	3	3	3	3	3	3

No.	Name	Type	20:0	20:1	20:2	22:0	22:2	24:0	24:1
M70	marsh-elder	seed	3.42	0.47	0.44	2.36	1.06	0.95	0.57
M102	arrowgrass	seed	2.12	0.15	0.06	2.25	0.00	1.31	0.00
M116	arrowgrass	seed	1.20	0.18	0.06	1.11	0.00	0.82	0.00
		Mean	2.25	0.26	0.19	1.91	0.35	1.03	0.19
		Std Dev	1.11	0.18	0.22	0.69	0.61	0.25	0.33
		Count	3	3	3	3	3	3	3

CLUSTER X - MIXED

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1
M40	juniper	berry	3.86	0.35	1.95	0.00	0.00	0.34	8.68	0.27	0.14
M71	*Rumex*	seeds	0.00	0.00	0.17	0.00	0.13	0.26	12.02	1.61	0.27
M132	muskrat	meat	0.04	0.00	0.87	0.03	0.59	0.00	16.86	1.48	0.00
M99	gooseberry	berry	0.03	0.00	0.34	0.00	0.09	0.00	8.58	0.68	0.31
M106	gooseberry	berry	0.07	0.00	0.29	0.00	0.12	0.00	8.25	0.52	0.76
M109	blueberry	berry	0.05	0.01	0.11	0.00	0.09	0.00	6.88	0.00	0.08
M41	*Chenopod.*	seed	0.15	0.06	0.90	0.00	0.22	0.04	11.68	0.64	0.49
M44	*Chenopod.*	seed	0.08	0.00	0.31	0.00	0.13	0.08	9.69	0.77	0.00
		Mean	0.53	0.05	0.62	0.00	0.17	0.09	10.33	0.75	0.26
		Std Dev	1.34	0.12	0.62	0.01	0.18	0.13	3.16	0.55	0.26
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	16:2	17:0	17:1	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0
M40	juniper	berry	0.00	0.35	0.00	3.39	14.84	0.00	36.43	0.00	0.27
M71	*Rumex*	seeds	0.69	0.19	0.19	1.42	17.98	1.59	36.16	0.34	0.00
M132	muskrat	meat	0.06	1.04	0.41	6.08	15.24	1.92	34.83	0.00	0.19
M99	gooseberry	berry	0.00	0.15	0.00	1.56	11.33	0.00	35.66	7.32	0.00
M106	gooseberry	berry	0.09	0.16	0.12	2.02	14.45	0.00	37.21	9.69	0.00
M109	blueberry	berry	0.00	0.17	0.10	1.71	17.19	0.00	41.70	0.03	0.00
M41	*Chenopod.*	seed	0.20	0.25	0.00	1.59	16.88	0.00	44.15	0.22	0.00
M44	*Chenopod.*	seed	0.35	0.21	0.34	1.65	12.40	1.14	47.75	0.00	0.06
		Mean	0.17	0.32	0.15	2.43	15.04	0.58	39.24	2.20	0.07
		Std Dev	0.24	0.30	0.16	1.61	2.32	0.83	4.72	3.94	0.11
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	18:3	18:4	20:0	20:1	20:2	20:3w6	20:4w6	20:3w3	20:5
M40	juniper	berry	20.66	0.00	0.57	1.14	3.35	0.00	0.00	0.00	0.00
M71	*Rumex*	seeds	18.24	0.00	1.61	0.56	0.31	0.00	0.00	0.00	0.00
M132	muskrat	meat	17.61	0.00	0.32	0.28	0.46	0.18	0.51	0.36	0.11
M99	gooseberry	berry	26.14	3.19	0.98	0.18	0.08	0.00	0.00	0.00	0.00
M106	gooseberry	berry	18.68	3.66	1.54	0.16	0.11	0.00	0.00	0.00	0.00
M109	blueberry	berry	28.76	0.00	1.32	0.25	0.12	0.00	0.00	0.00	0.00
M41	*Chenopod.*	seed	10.20	0.00	1.70	1.54	0.18	0.00	0.00	0.00	0.00
M44	*Chenopod.*	seed	17.86	0.00	0.84	1.04	0.16	0.00	0.00	0.00	0.00
		Mean	19.77	0.86	1.11	0.64	0.60	0.02	0.06	0.04	0.01
		Std Dev	5.68	1.59	0.51	0.53	1.12	0.06	0.18	0.13	0.04
		Count	8	8	8	8	8	8	8	8	8

No.	Name	Type	22:0	22:1	22:2	22:5	24:0	22:6	24:1
M40	juniper	berry	2.03	0.00	0.00	0.00	0.95	0.00	0.42
M71	*Rumex*	seeds	1.76	1.32	0.00	0.00	2.70	0.00	0.47
M132	muskrat	meat	0.07	0.00	0.02	0.37	0.00	0.07	0.00
M99	gooseberry	berry	1.36	0.03	0.00	0.00	1.90	0.00	0.08
M106	gooseberry	berry	0.00	0.02	0.00	0.00	2.03	0.00	0.05
M109	blueberry	berry	0.46	0.00	0.00	0.00	0.56	0.00	0.41
M41	*Chenopod.*	seed	3.26	1.67	0.17	0.00	1.80	0.00	2.04
M44	*Chenopod.*	seed	1.47	1.35	0.12	0.00	0.63	0.00	1.58
		Mean	1.30	0.55	0.04	0.05	1.32	0.01	0.63
		Std Dev	1.10	0.75	0.07	0.13	0.92	0.03	0.76
		Count	8	8	8	8	8	8	8

CLUSTER XI - GREENS

No.	Common Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9
M6	false solomon's	greens	0.86	0.00	0.85	1.01	0.73	0.30	18.34	1.87
M7	false solomon's	greens	0.74	0.00	0.53	1.23	0.39	0.97	18.13	4.51
M42	fireweed	root	0.00	0.00	0.34	0.00	0.46	0.00	25.83	1.58
M43	false solomon's	greens	0.05	0.00	0.52	2.19	0.50	0.43	25.07	2.99
M37	violet	greens	0.19	0.20	0.81	2.44	0.21	0.00	19.90	5.48
M50	violet	greens	0.00	0.00	0.43	2.64	0.17	1.06	17.77	7.00
M115	false solomon's	greens	0.01	0.00	0.27	0.00	0.32	1.17	19.85	6.52
M15	arrow grass	seed	0.20	0.00	0.38	0.00	0.14	0.27	16.20	0.75
M78	Hidat. red beans	bean	0.00	0.00	0.09	0.00	0.06	0.00	13.71	0.00
M125	false solomon's	green	0.54	0.00	0.46	0.00	0.40	1.24	21.37	4.90
M19	waterhorehound	greens	2.43	0.91	0.64	0.00	0.83	0.00	18.53	8.00
M45	golden rod	greens	0.20	0.00	1.10	0.00	0.35	0.68	20.92	6.04
M46	fireweed	greens	0.00	0.00	0.79	0.00	0.19	0.63	20.76	6.45
M66	fireweed	greens	0.00	0.00	1.57	0.00	0.19	1.51	16.31	10.45
M67	fireweed	greens	0.16	0.00	2.76	0.00	0.26	1.21	17.45	8.44
M68	fireweed	greens	0.00	0.00	2.12	0.00	0.24	0.77	18.41	5.82
M87	golden rod	greens	0.13	0.12	0.55	0.00	0.40	1.60	17.57	7.90
M86	*Chenopodium*	greens	0.14	0.00	1.20	0.00	0.14	1.62	19.03	8.93
M114	*Chenopodium*	greens	0.00	0.00	0.49	0.00	0.30	2.17	17.97	12.51
M119	golden rod	greens	0.33	0.29	1.24	0.00	0.67	1.52	17.85	7.99
M117	*Rumex*	greens	0.31	0.00	0.65	0.00	0.22	1.57	19.25	8.80
M127	Rumex	greens	0.15	0.00	0.35	0.04	0.11	2.04	17.04	7.49
M122	sarsaparilla	greens	0.00	0.00	0.49	0.00	0.00	1.88	20.15	7.58
M101	stinging nettle	greens	0.06	0.00	0.41	0.00	0.03	2.45	14.13	10.14
M47	sarsaparilla	greens	0.18	0.00	1.76	0.00	0.14	1.68	16.11	10.05
		Mean	0.27	0.06	0.83	0.38	0.30	1.07	18.71	6.49
		Std Dev	0.51	0.19	0.64	0.83	0.21	0.74	2.78	3.18
		Count	25	25	25	25	25	25	25	25

No.	Common Name	Type	16:1	16:2	17:0	17:1	18:0	18:1w9	18:1w11	18:2
M6	false solomon's	greens	0.13	0.78	0.69	0.17	3.08	3.33	0.58	21.25
M7	false solomon's	greens	0.20	0.63	0.36	0.07	2.24	5.44	0.47	22.05
M42	fireweed	root	0.00	0.22	0.54	0.00	2.79	3.98	1.69	21.95
M43	false solomon's	greens	0.00	0.98	0.77	0.46	2.36	1.24	0.52	28.93
M37	violet	greens	0.00	1.82	0.35	0.18	2.34	5.87	0.73	20.22
M50	violet	greens	0.00	2.12	0.23	0.00	1.92	6.67	0.00	26.41
M115	false solomon's	greens	0.00	1.21	0.40	0.59	2.08	1.40	0.74	29.80
M15	arrow grass	seed	0.50	0.15	0.32	0.00	3.58	9.27	1.19	30.59
M78	Hidat. red beans	bean	0.08	0.00	0.19	0.00	2.32	8.61	2.27	34.74
M125	false solomon's	green	0.00	0.76	0.49	0.53	2.05	2.56	0.62	24.10
M19	waterhorehound	greens	0.40	1.65	0.46	0.14	5.11	5.58	0.00	10.35
M45	golden rod	greens	0.00	2.41	0.34	0.00	2.21	1.57	0.00	15.84
M46	fireweed	greens	0.00	2.38	0.28	0.24	2.25	1.44	0.70	17.60
M66	fireweed	greens	0.00	2.41	0.41	0.00	2.89	1.64	0.77	9.03
M67	fireweed	greens	0.00	2.18	0.49	0.00	3.87	2.87	0.80	13.48
M68	fireweed	greens	0.00	2.02	0.43	0.00	2.44	2.52	1.07	15.24
M87	golden rod	greens	0.00	2.06	0.26	0.00	2.29	3.01	0.00	15.89
M86	*Chenopodium*	greens	0.00	1.84	0.19	2.20	1.67	5.83	0.00	13.73
M114	*Chenopodium*	greens	0.00	2.70	0.30	1.57	1.14	7.02	0.00	12.96

CLUSTER XI - GREENS cont'd

No.	Common Name	Type	16:1	16:2	17:0	17:1	18:0	18:1w9	18:1w11	18:2
M119	golden rod	greens	0.00	1.88	0.90	0.00	2.89	1.61	0.00	16.84
M117	*Rumex*	greens	0.00	1.19	0.27	0.33	2.01	10.77	0.00	15.81
M127	Rumex	greens	0.00	2.44	0.20	0.00	1.52	8.08	0.91	12.34
M122	sarsaparilla	greens	0.00	1.95	0.37	0.00	3.05	5.03	0.00	14.85
M101	stinging nettle	greens	0.00	1.71	0.21	0.00	2.14	2.08	0.89	18.74
M47	sarsaparilla	greens	0.93	1.75	0.28	0.12	1.75	3.29	1.11	7.83
		Mean	0.09	1.57	0.39	0.26	2.48	4.43	0.60	18.82
		Std Dev	0.22	0.78	0.18	0.53	0.83	2.78	0.59	7.10
		Count	25	25	25	25	25	25	25	25

No.	Common Name	Type	18:3w6	19:0	18:3	20:0	20:1	20:2	22:0	22:1
M6	false solomon's	greens	0.00	0.12	38.28	1.32	0.19	0.00	2.49	0.28
M7	false solomon's	greens	0.00	0.07	35.56	1.33	0.24	0.00	2.04	0.32
M42	fireweed	root	0.14	0.21	29.42	3.29	0.39	0.31	1.67	0.26
M43	false solomon's	greens	0.00	0.30	25.16	0.99	0.26	0.75	2.41	0.00
M37	violet	greens	0.00	0.00	30.64	0.86	0.00	0.32	1.98	0.22
M50	violet	greens	0.00	0.00	31.74	0.30	0.23	0.26	0.61	0.00
M115	false solomon's	greens	0.05	0.06	29.72	0.81	0.68	0.28	1.82	0.15
M15	arrow grass	seed	0.00	0.09	27.21	3.10	0.23	0.00	3.99	0.25
M78	Hidat. red beans	bean	0.00	0.00	35.35	0.45	0.17	0.08	0.74	0.00
M125	false solomon's	green	0.00	0.00	33.67	1.17	0.35	0.21	2.28	0.00
M19	waterhorehound	greens	0.21	0.00	30.71	3.61	0.82	0.00	4.24	0.56
M45	golden rod	greens	0.00	0.00	39.32	1.83	0.25	0.29	1.57	0.76
M46	fireweed	greens	0.00	0.00	38.53	1.96	0.00	0.34	1.84	0.38
M66	fireweed	greens	1.34	0.00	39.28	3.60	0.09	0.00	3.28	0.31
M67	fireweed	greens	0.30	0.31	34.92	3.90	0.15	0.00	2.13	0.33
M68	fireweed	greens	1.69	0.00	39.68	2.51	0.16	0.00	1.52	0.31
M87	golden rod	greens	0.11	0.14	40.43	1.82	0.30	0.16	1.68	0.00
M86	*Chenopodium*	greens	0.23	0.00	35.48	2.16	0.07	0.00	2.73	0.21
M114	*Chenopodium*	greens	0.17	0.00	34.30	1.63	0.08	0.00	2.50	0.00
M119	golden rod	greens	0.00	0.32	38.43	2.69	0.00	0.00	1.82	0.00
M117	*Rumex*	greens	0.05	0.00	33.14	0.69	0.45	0.26	1.10	0.22
M127	Rumex	greens	0.00	0.00	42.08	1.00	0.37	0.10	1.27	0.14
M122	sarsaparilla	greens	0.00	0.00	35.61	2.11	0.54	0.00	2.89	0.00
M101	stinging nettle	greens	0.05	0.07	30.85	2.98	0.08	0.26	3.19	0.00
M47	sarsaparilla	greens	0.00	0.00	47.52	0.65	0.00	0.00	0.91	0.00
		Mean	0.17	0.07	35.08	1.87	0.24	0.14	2.11	0.19
		Std Dev	0.41	0.11	5.08	1.09	0.21	0.18	0.93	0.20
		Count	25	25	25	25	25	25	25	25

No.	Common Name	Type	22:2	24:0	24:1
M6	false solomon's	greens	0.00	3.18	0.17
M7	false solomon's	greens	0.00	2.39	0.10
M42	fireweed	root	0.00	2.21	2.68
M43	false solomon's	greens	0.00	2.66	0.00
M37	violet	greens	0.00	5.24	0.00
M50	violet	greens	0.00	0.44	0.00
M115	false solomon's	greens	0.00	1.86	0.08
M15	arrow grass	seed	0.00	1.58	0.00
M78	Hidat. red beans	bean	0.00	0.93	0.22

CLUSTER XI - GREENS cont'd

No.	Common Name	Type	22:2	24:0	24:1
M125	false solomon's	green	0.00	2.32	0.00
M19	waterhorehound	greens	0.26	3.50	1.07
M45	golden rod	greens	1.32	1.92	1.07
M46	fireweed	greens	0.26	2.96	0.00
M66	fireweed	greens	0.21	4.52	0.21
M67	fireweed	greens	0.00	2.83	1.18
M68	fireweed	greens	0.00	2.21	0.85
M87	golden rod	greens	0.00	2.88	0.70
M86	*Chenopodium*	greens	0.00	2.61	0.00
M114	*Chenopodium*	greens	0.00	2.19	0.00
M119	golden rod	greens	0.00	1.52	1.19
M117	*Rumex*	greens	0.00	2.92	0.00
M127	Rumex	greens	0.00	2.35	0.00
M122	sarsaparilla	greens	0.00	3.49	0.00
M101	stinging nettle	greens	0.03	9.51	0.00
M47	sarsaparilla	greens	0.00	1.40	2.55
		Mean	0.08	2.79	0.48
		Std Dev	0.27	1.74	0.77
		Count	25	25	25

CLUSTER XII - BERRIES

No.	Name	Type	12:0	14:0	14:1	15:0	16:0	16:1w9	16:1	17:0	17:1
M12	rosehips	berry	0.71	0.30	0.00	0.12	3.31	0.08	0.31	0.08	0.11
M13	rosehips	berry	0.87	0.58	0.06	0.15	6.64	0.22	0.52	0.29	0.15
M93	bearberry	berry	0.04	0.24	0.00	0.00	0.41	0.00	0.08	0.09	0.00
M103	rosehips	hips	0.16	0.14	0.00	0.05	3.13	0.00	0.29	0.09	0.10
M108	rosehips	hips	0.22	0.11	0.00	0.06	3.11	0.06	0.17	0.09	0.09
M38	bearberry	berry	0.07	0.30	0.00	0.00	4.22	0.00	0.17	0.09	0.00
		Mean	0.34	0.28	0.01	0.06	3.47	0.06	0.25	3.47	0.08
		Std Dev	0.35	0.17	0.03	0.06	2.01	0.09	0.15	0.08	0.06
		Count	6	6	6	6	6	6	6	6	6

No.	Name	Type	18:0	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3	20:0	20:1
M12	rosehips	berry	1.25	17.73	0.83	32.37	0.00	0.06	40.44	0.80	0.68
M13	rosehips	berry	2.48	13.35	0.73	26.96	0.00	0.69	38.20	2.69	0.54
M93	bearberry	berry	0.84	13.93	0.00	25.46	0.00	0.00	45.12	0.32	0.48
M103	rosehips	hips	1.19	17.83	0.00	35.68	0.00	0.04	38.55	0.89	0.69
M108	rosehips	hips	1.17	14.19	0.00	37.50	0.02	0.00	40.12	0.90	0.74
M38	bearberry	berry	1.12	11.11	0.00	16.51	0.00	0.00	36.07	0.48	0.45
		Mean	1.34	14.69	0.26	29.08	0.00	0.13	39.75	1.01	0.60
		Std Dev	0.58	2.63	0.40	7.76	0.01	0.27	3.06	0.85	0.12
		Count	6	6	6	6	6	6	6	6	6

No.	Name	Type	20:2	22:0	22:1	22:2	24:0	24:1
M12	rosehips	berry	0.00	0.36	0.21	0.00	0.27	0.00
M13	rosehips	berry	0.00	2.60	0.00	0.00	2.13	0.16
M93	bearberry	berry	0.22	4.01	0.03	0.00	8.49	0.24
M103	rosehips	hips	0.13	0.59	0.00	0.00	0.42	0.02
M108	rosehips	hips	0.20	0.71	0.00	0.00	0.53	0.02
M38	bearberry	berry	0.19	9.27	0.14	0.14	19.21	0.44
		Mean	0.12	2.92	0.06	0.02	5.17	0.15
		Std Dev	0.10	3.42	0.09	0.06	7.56	0.17
		Count	6	6	6	6	6	6

CLUSTER XIII - ROOTS

No.	Common Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1	16:2	17:0	17:1	18:0	18:1w9	18:1w11
M9	waterparsnip	root	3.87	0.93	3.17	1.49	3.66	0.00	19.64	0.65	2.28	0.48	0.78	0.00	5.06	8.67	1.18
M96	waterparsnip	root	6.41	0.62	1.45	1.21	9.12	0.00	15.95	0.00	0.60	2.81	0.67	0.00	4.00	4.17	1.39
M97	Jer. artichoke	root	3.88	0.63	1.22	0.00	5.63	0.00	20.95	0.00	0.74	5.10	1.30	0.67	2.02	4.27	1.31
M18	giant reed	root	0.00	0.00	0.40	0.06	0.16	0.00	16.95	0.14	0.17	0.27	0.42	0.17	2.86	9.30	0.80
M58	cat tail	root	0.09	0.00	0.49	0.00	0.98	0.00	17.01	0.00	1.17	0.00	0.63	0.29	3.37	3.65	1.59
M121	giant reed	root	0.00	0.00	0.36	0.00	0.51	0.29	23.42	0.48	0.00	0.00	0.40	0.00	2.50	4.83	0.78
M94	ostrich fern	root	0.10	0.00	0.28	0.00	0.87	0.00	32.36	0.75	1.58	3.81	0.51	0.41	2.07	6.90	3.09
M100	red osier	berry	0.00	0.00	0.07	0.00	0.03	0.00	26.60	0.00	1.25	0.18	0.07	0.05	1.36	12.80	3.67
M10	sarsaparilla	root	0.19	0.07	0.63	0.00	0.43	0.31	21.63	0.73	0.76	2.00	0.74	0.77	3.20	8.94	2.43
M11	saskatoon	berry	0.38	0.00	0.50	0.00	0.22	0.00	17.84	0.07	0.74	0.00	0.39	0.00	4.88	11.17	0.82
M17	waterhorehound	root	0.00	0.00	0.55	0.30	0.41	0.00	19.09	0.57	0.30	6.14	0.74	0.48	4.74	9.71	2.27
M57	bulrush	root	0.19	0.10	0.45	0.00	0.49	0.00	26.14	0.00	1.15	0.00	0.51	0.00	0.00	8.44	4.75
M72	bulrush	roots	0.00	0.00	0.84	0.00	1.16	0.00	24.85	0.94	3.18	0.58	0.74	0.00	2.05	7.34	5.13
M74	bulrush	roots	0.26	0.13	0.74	0.00	2.23	0.00	22.16	3.04	0.00	0.00	1.13	0.00	3.48	14.41	0.00
M75	bulrush	roots	0.00	0.00	0.42	0.00	0.49	0.00	30.01	0.00	1.02	0.00	0.46	0.00	2.06	10.61	3.90
M89	bur-reed	roots	0.27	0.00	1.01	0.00	0.69	0.00	19.74	1.66	2.02	0.00	0.67	0.00	3.03	15.16	4.82
M111	wound wort	roots	0.00	0.13	0.38	0.00	0.20	0.59	21.20	4.54	1.79	0.00	0.83	0.00	2.81	10.63	0.00
M61	cat tail	root	0.71	0.00	0.96	0.00	1.35	0.34	26.84	3.40	0.00	0.00	1.38	0.19	7.45	5.13	1.37
M64	fireweed	roots	0.00	0.00	0.61	0.00	0.40	0.00	29.09	0.73	1.01	0.36	0.81	0.68	4.20	5.22	5.64
M65	fireweed	roots	0.00	0.00	0.47	0.00	0.35	0.00	33.19	0.00	2.11	0.00	0.85	0.00	4.14	6.18	6.60
M84	mare's tail	greens	0.14	0.00	0.85	0.00	0.21	1.74	29.79	10.03	0.00	1.07	0.34	0.00	4.39	10.90	0.00
M63	fireweed	roots	0.07	0.00	0.67	0.00	0.23	0.00	19.35	0.00	0.39	1.02	0.53	0.57	3.31	23.20	6.49
M83	*Chenopodium*	seed	0.07	0.07	0.68	0.16	0.59	0.60	18.74	3.92	0.00	1.39	0.33	0.70	2.06	15.70	0.00
M92	*Rumex*	seed	0.07	0.00	0.37	0.00	0.17	0.36	15.30	2.65	0.00	0.60	0.26	0.28	1.89	16.53	0.00
M110	chickweed	greens	0.23	0.00	1.52	0.00	0.51	0.00	19.13	3.83	0.00	0.86	0.64	0.00	1.87	11.02	0.00
		Mean	0.68	0.11	0.76	0.13	1.24	0.17	22.68	1.52	0.89	1.07	0.65	0.21	3.15	9.79	2.32
		Std Dev	1.59	0.24	0.61	0.38	2.06	0.38	5.26	2.30	0.87	1.68	0.31	0.28	1.52	4.67	2.19
		Count	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25

CLUSTER XIII - ROOTS cont'd

No.	Common Name	Type	18:2	18:3w6	19:0	18:3	18:4	20:0	20:1	20:2	22:0	22:1	22:2	24:0	24:1
M9	waterparsnip	root	31.85	0.00	0.12	5.77	0.00	2.55	1.21	0.85	2.77	2.34	0.00	0.69	0.00
M96	waterparsnip	root	31.53	0.00	0.83	4.85	0.00	3.70	0.35	0.68	6.14	0.00	0.00	3.52	0.00
M97	Jer. artichoke	root	32.76	0.00	0.00	7.33	0.00	0.82	0.66	0.39	5.04	0.92	1.08	1.97	1.29
M18	giant reed	root	36.09	0.15	0.26	6.18	0.27	11.26	5.12	0.27	3.79	0.41	0.11	4.20	0.19
M58	cat tail	root	33.31	0.00	0.70	7.10	0.00	7.05	0.96	0.57	8.85	0.17	0.00	11.82	0.23
M121	giant reed	root	27.04	0.00	0.37	7.46	0.00	14.39	9.04	0.00	2.92	0.62	0.00	4.58	0.00
M94	ostrich fern	root	34.79	0.22	0.00	6.50	0.00	0.81	0.18	0.33	1.65	0.00	0.00	2.80	0.00
M100	red osier	berry	38.09	0.00	0.00	14.76	0.00	0.16	0.24	0.06	0.14	0.01	0.00	0.44	0.02
M10	sarsaparilla	root	29.84	0.29	0.00	10.18	0.00	2.90	0.28	0.21	6.83	1.90	0.00	4.72	0.00
M11	saskatoon	berry	26.80	0.00	0.00	7.41	0.00	8.40	0.34	0.00	15.46	0.00	0.00	4.35	0.22
M17	waterhorehound	root	26.39	0.00	0.20	11.25	0.00	3.06	0.35	0.00	6.55	0.49	0.00	5.17	1.23
M57	bulrush	root	30.75	0.22	0.23	8.37	0.00	1.58	1.33	0.00	5.30	0.44	0.26	9.30	0.00
M72	bulrush	roots	16.42	1.24	0.40	8.70	0.00	2.72	0.48	0.22	8.02	0.00	0.00	14.59	0.39
M74	bulrush	roots	14.90	0.61	0.52	5.53	0.00	2.19	0.43	0.00	8.87	0.00	0.00	19.04	0.34
M75	bulrush	roots	22.98	0.47	0.00	10.24	0.00	1.67	0.28	0.00	4.86	0.48	0.00	9.03	1.01
M89	bur-reed	roots	20.11	1.20	0.60	3.73	0.00	4.33	1.11	0.00	5.23	0.00	0.00	14.64	0.00
M111	wound wort	roots	23.16	0.00	0.19	12.17	0.97	2.73	0.37	0.00	7.44	0.00	0.19	8.83	0.85
M61	cat tail	root	13.56	0.00	0.60	2.77	1.14	6.40	0.45	0.27	0.00	0.00	0.00	25.68	0.00
M64	fireweed	roots	20.52	0.00	0.36	13.91	6.23	4.35	1.26	0.16	2.22	0.00	0.00	1.95	0.29
M65	fireweed	roots	20.99	0.37	0.46	11.62	2.78	5.75	0.36	0.24	2.38	0.00	0.00	1.17	0.00
M84	mare's tail	greens	21.26	0.78	0.00	9.29	0.00	2.50	0.14	0.00	3.28	0.00	0.00	3.28	0.00
M63	fireweed	roots	22.01	0.40	0.17	11.84	4.73	0.30	0.56	0.19	1.60	0.96	0.00	0.97	0.42
M83	*Chenopodium*	seed	24.25	0.35	0.00	20.33	0.00	1.63	0.64	0.27	2.81	0.25	0.00	4.32	0.14
M92	*Rumex*	seed	24.71	0.31	0.00	18.67	0.00	0.89	1.42	0.49	2.97	0.35	0.00	11.56	0.14
M110	chickweed	greens	31.96	3.45	0.00	15.05	1.60	1.02	0.52	0.60	1.92	0.00	0.00	4.18	0.11
		Mean	26.24	0.40	0.24	9.64	0.71	3.73	1.12	0.23	4.68	0.37	0.07	6.91	0.27
		Std Dev	6.72	0.73	0.26	4.43	1.60	3.50	1.92	0.25	3.40	0.61	0.22	6.32	0.39
		Count	25	25	25	25	25	25	25	25	25	25	25	25	25

CLUSTER XIV - GREENS

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	br16:0	16:0	16:1w9	16:1	16:2	17:0	17:1	18:0	18:1w9	18:1w11
M25	cowparsnip	greens	0.77	0.60	3.12	1.79	0.27	2.22	13.70	8.34	0.00	1.94	0.62	5.23	2.29	2.40	1.06
M26	cowparsnip	stalk	0.59	0.00	0.89	1.53	0.71	1.77	21.01	6.68	0.00	0.88	0.77	4.26	3.22	1.46	0.55
M28	cowparsnip	flower	0.18	0.00	0.62	0.27	0.65	0.33	20.05	1.34	0.12	0.10	3.63	0.47	2.85	5.62	0.00
M35	sarsaparilla	greens	0.63	0.12	0.89	0.00	0.30	0.45	23.17	4.05	0.67	1.86	0.51	2.55	2.07	2.29	0.52
M76	arrowhead	roots	0.12	0.00	0.63	0.00	0.65	0.36	20.30	2.13	1.54	0.48	0.68	0.14	7.17	1.49	1.50
M52	cat tail	greens	1.54	0.00	2.10	0.00	0.38	1.38	28.74	9.57	0.00	0.86	1.04	0.00	6.57	8.90	0.00
M53	cat tail	greens	0.03	0.00	0.63	0.00	0.57	0.73	22.37	5.72	0.00	1.54	0.71	0.00	3.96	1.41	0.00
M55	bulrush	greens	0.21	0.12	0.95	0.00	1.33	1.20	29.74	7.28	1.79	1.23	1.25	0.36	2.48	3.79	1.55
M56	bulrush	greens	0.05	0.00	1.38	0.00	0.92	1.32	33.81	8.93	0.00	1.09	1.00	0.00	2.92	3.29	1.32
M62	cat tail	greens	0.46	0.00	0.88	0.00	0.79	0.93	23.76	6.76	0.00	0.78	0.93	0.54	4.85	1.91	0.56
M69	bulrush	greens	0.00	0.00	0.59	0.00	0.67	0.89	27.99	7.33	0.00	0.99	0.93	0.00	3.03	4.44	0.80
M90	golden rod	greens	0.27	0.00	1.46	0.00	0.34	2.23	28.27	12.15	0.00	1.65	0.53	0.00	3.38	1.88	0.00
M120	golden rod	greens	1.71	0.00	2.51	0.13	0.55	2.66	24.90	9.57	0.00	2.36	1.32	0.00	3.25	2.16	0.00
M34	silverberry	berry	0.00	0.00	0.35	0.00	0.29	0.00	20.88	1.51	0.84	0.52	0.40	0.15	3.24	2.96	4.86
		Mean	0.47	0.06	1.21	0.27	0.60	1.18	24.19	6.53	0.35	1.16	1.02	0.98	3.66	3.14	0.91
		Std Dev	0.55	0.16	0.82	0.60	0.29	0.81	5.14	3.27	0.62	0.64	0.80	1.74	1.53	2.06	1.27
		Count	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

No.	Name	Type	18:2	18:3w6	19:0	18:3	18:4	20:0	20:1	20:2	22:0	22:1	22:2	24:0	24:1
M25	cowparsnip	greens	20.25	0.00	0.00	21.57	0.00	1.99	0.00	0.00	3.01	0.00	0.00	8.82	0.00
M26	cowparsnip	stalk	26.24	0.00	0.15	15.53	0.00	2.87	0.27	0.18	4.12	0.00	0.00	6.32	0.00
M28	cowparsnip	flower	26.02	2.71	0.00	21.42	0.00	1.76	1.49	0.28	2.94	0.33	0.13	6.46	0.21
M35	sarsaparilla	greens	22.99	0.56	0.00	17.17	0.00	2.79	0.41	0.30	4.63	0.37	0.38	10.32	0.00
M76	arrowhead	roots	18.41	0.13	0.16	13.22	1.77	1.35	0.17	0.14	2.59	0.00	0.00	24.59	0.27
M52	cat tail	greens	8.05	0.00	0.29	13.22	0.00	3.07	0.26	0.00	5.95	0.00	0.00	8.10	0.00
M53	cat tail	greens	14.54	0.15	0.38	21.54	0.00	5.18	0.20	0.23	8.67	0.00	0.00	11.15	0.00
M55	bulrush	greens	11.33	0.45	0.41	14.87	0.00	2.52	0.26	0.12	6.31	0.00	0.17	10.16	0.13
M56	bulrush	greens	9.83	0.47	0.49	12.34	0.00	3.09	0.32	0.00	5.69	0.00	0.00	11.30	0.00
M62	cat tail	greens	13.15	0.24	0.63	10.06	0.64	6.35	0.33	0.27	9.98	0.00	0.00	15.20	0.00
M69	bulrush	greens	15.56	0.42	0.40	21.17	0.00	2.77	0.31	0.14	3.80	0.00	0.00	7.77	0.00
M90	golden rod	greens	8.62	0.14	0.19	27.01	0.00	3.33	0.00	0.00	2.34	0.00	0.00	5.29	0.90
M120	golden rod	greens	15.26	0.00	0.00	22.85	0.00	4.04	0.00	0.00	2.65	0.00	0.00	2.95	1.13
M34	silverberry	berry	15.81	0.31	0.00	18.38	0.00	4.08	0.12	0.09	17.70	0.00	0.00	7.53	0.00
		Mean	16.15	0.40	0.22	17.88	0.17	3.23	0.30	0.13	5.74	0.05	0.05	9.71	0.19
		Std Dev	5.99	0.69	0.21	4.88	0.49	1.34	0.37	0.11	4.15	0.13	0.11	5.23	0.36
		Count	14	14	14	14	14	14	14	14	14	14	14	14	14

CLUSTER XV - ROOT

No.	Name	Type	12:0	14:0	15:0	16:0	16:1w9	16:1	17:0	17:1	18:0
M51	cat tail	root	0.17	0.49	1.10	22.52	1.10	1.76	1.37	2.38	6.12
M60	cat tail	root	0.12	0.47	0.83	14.91	0.71	0.77	0.90	0.45	5.76
		Mean	0.14	0.48	0.97	18.71	0.91	1.26	1.13	1.42	5.94
		Std Dev	0.04	0.02	0.19	5.38	0.28	0.70	0.33	1.36	0.25
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	18:1w9	18:1w11	18:2	18:3w6	19:0	18:3	20:0	20:1	20:2
M51	cat tail	root	0.94	0.00	14.67	1.20	1.34	4.20	11.31	0.55	0.36
M60	cat tail	root	4.58	1.16	16.55	0.58	1.28	2.64	11.73	0.72	0.45
		Mean	2.76	0.58	15.61	0.89	1.31	3.42	11.52	0.63	0.40
		Std Dev	2.57	0.82	1.33	0.44	0.04	1.11	0.30	0.12	0.07
		Count	2	2	2	2	2	2	2	2	2

No.	Name	Type	22:0	24:0	24:1
M51	cat tail	root	10.98	17.30	0.14
M60	cat tail	root	14.08	21.32	0.00
		Mean	12.53	19.31	0.07
		Std Dev	2.19	2.84	0.10
		Count	2	2	2

SAMPLES THAT DID NOT CLUSTER READILY

No.	Name	Type	12:0	13:0	14:0	14:1	15:0	16:0	16:1w9	16:1	16:2
M2	w-t deer	fat	0.06	0.03	2.32	0.05	0.54	22.60	0.55	0.79	1.06
M134	squirrel	meat	0.00	0.00	0.22	0.00	0.14	9.77	0.37	0.30	0.00
M131	grouse	bird	0.00	0.00	0.55	0.13	0.06	15.77	3.11	0.00	0.00
M59	cat tail	seed	0.08	0.10	0.25	0.00	1.03	9.16	0.00	0.44	0.00

No.	Name	Type	17:0	17:1	18:0	18:1w9	18:1w11	18:2	19:0	18:3	20:0
M2	w-t deer	fat	1.93	0.28	38.78	20.70	3.00	3.46	0.37	2.64	0.37
M134	squirrel	meat	0.32	0.00	7.98	16.31	2.39	43.66	0.00	0.75	0.15
M131	grouse	bird	0.21	0.11	13.25	16.07	3.21	17.95	0.00	6.86	0.08
M59	cat tail	seed	20.25	0.00	3.34	1.80	2.78	11.13	22.21	3.11	2.96

No.	Name	Type	20:1	20:2	20:3w6	20:4w6	20:3w3	20:5	22:0	22:1	22:2
M2	w-t deer	fat	0.10	0.00	0.08	0.10	0.04	0.00	0.08	0.00	0.00
M134	squirrel	meat	0.37	0.89	0.00	8.26	0.00	0.40	0.13	0.00	0.00
M131	grouse	bird	0.18	0.00	0.68	9.92	0.20	6.59	0.18	0.00	0.00
M59	cat tail	seed	0.27	0.53	0.00	0.00	0.00	0.00	13.55	0.63	0.28

No.	Name	Type	22:3	22:5	24:0	22:6
M2	w-t deer	fat	0.00	0.00	0.06	0.00
M134	squirrel	meat	0.00	0.57	0.00	7.02
M131	grouse	bird	0.22	2.81	0.00	1.85
M59	cat tail	seed	0.00	0.00	6.11	0.00

APPENDIX E

Bar graphs of the fatty acid composition
of experimental cooking residues

Figure E-1. Bar graphs comparing the fatty acid composition of uncooked bison to experimental cooking residues after four days and long term decomposition.

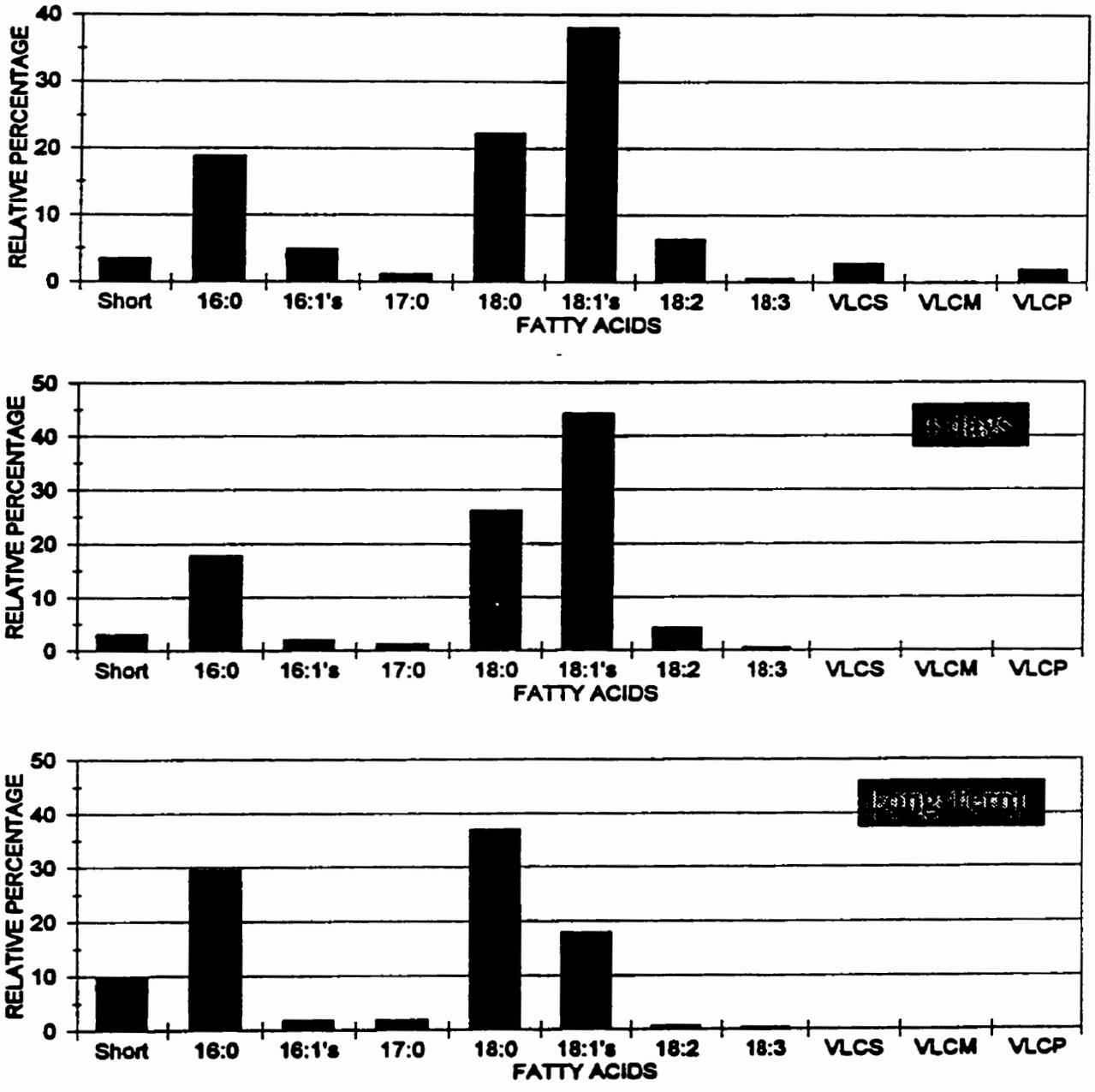


Figure E-2. Bar graphs comparing the fatty acid composition of uncooked sweet corn to experimental cooking residues after four days and long term decomposition.

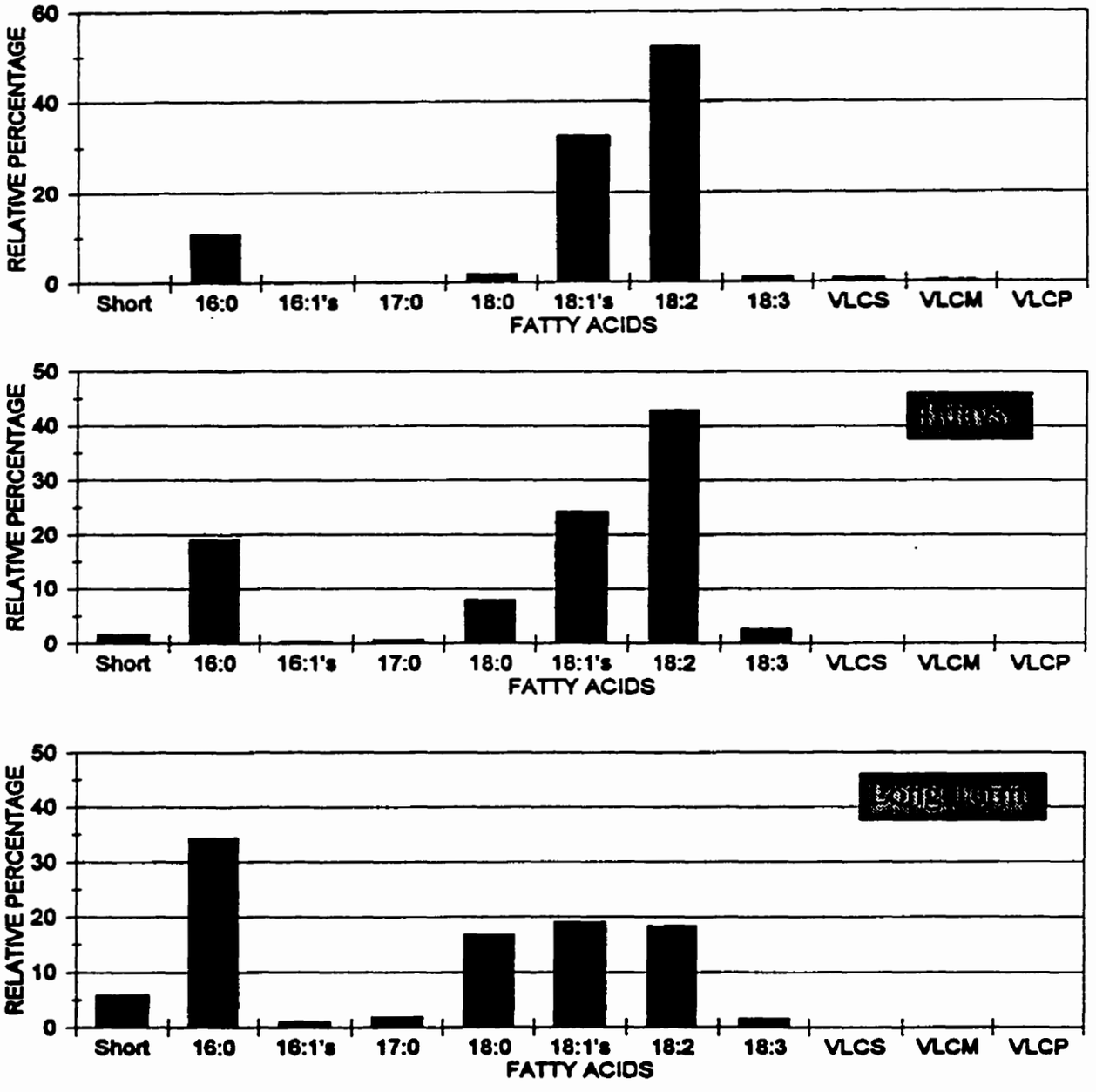


Figure E-3. Bar graphs comparing the fatty acid composition of uncooked catfish to experimental cooking residues after four days and long term decomposition.

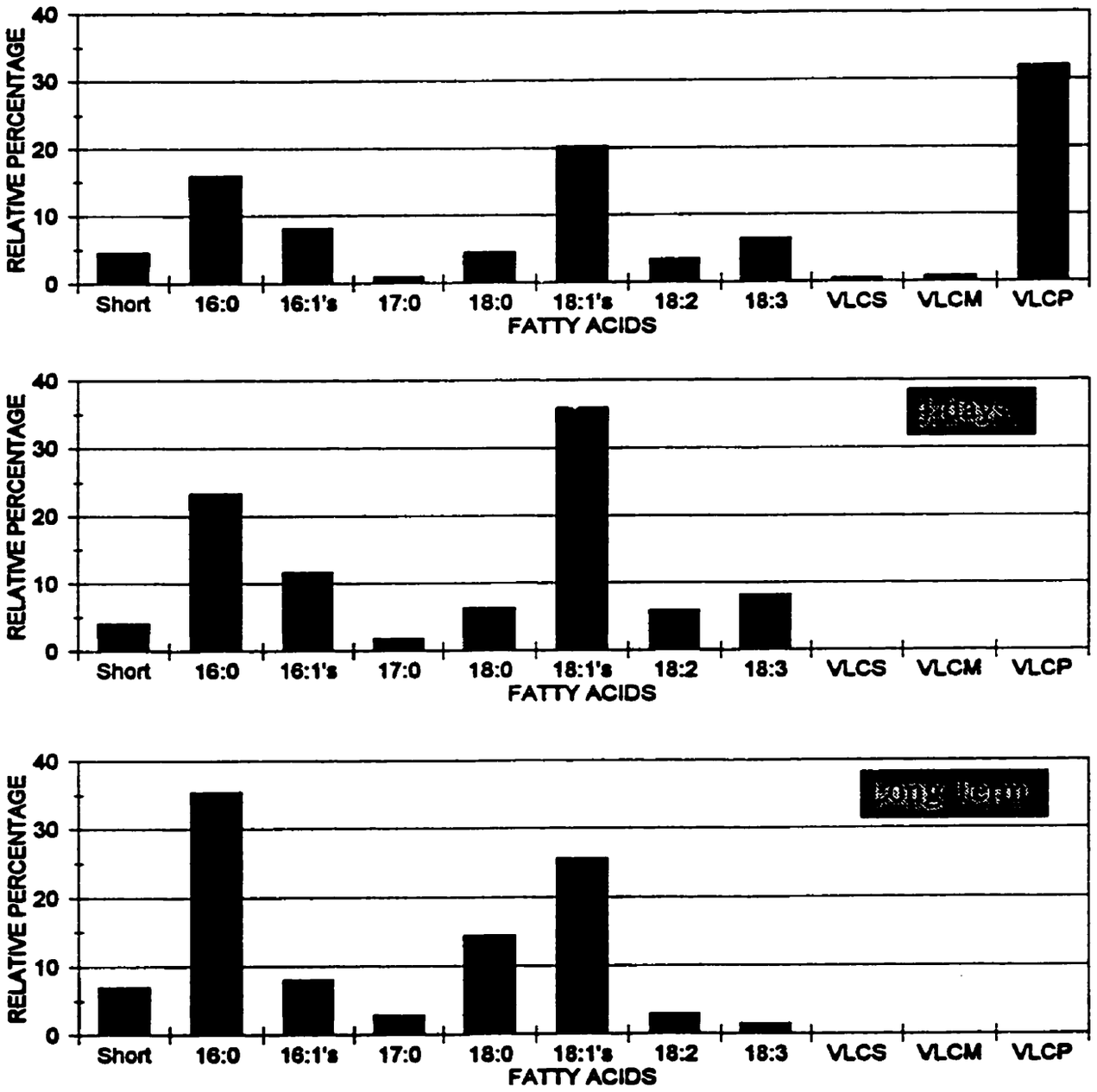


Figure E-4. Bar graphs comparing the fatty acid composition of uncooked deer meat to experimental cooking residues after four days and long term decomposition.

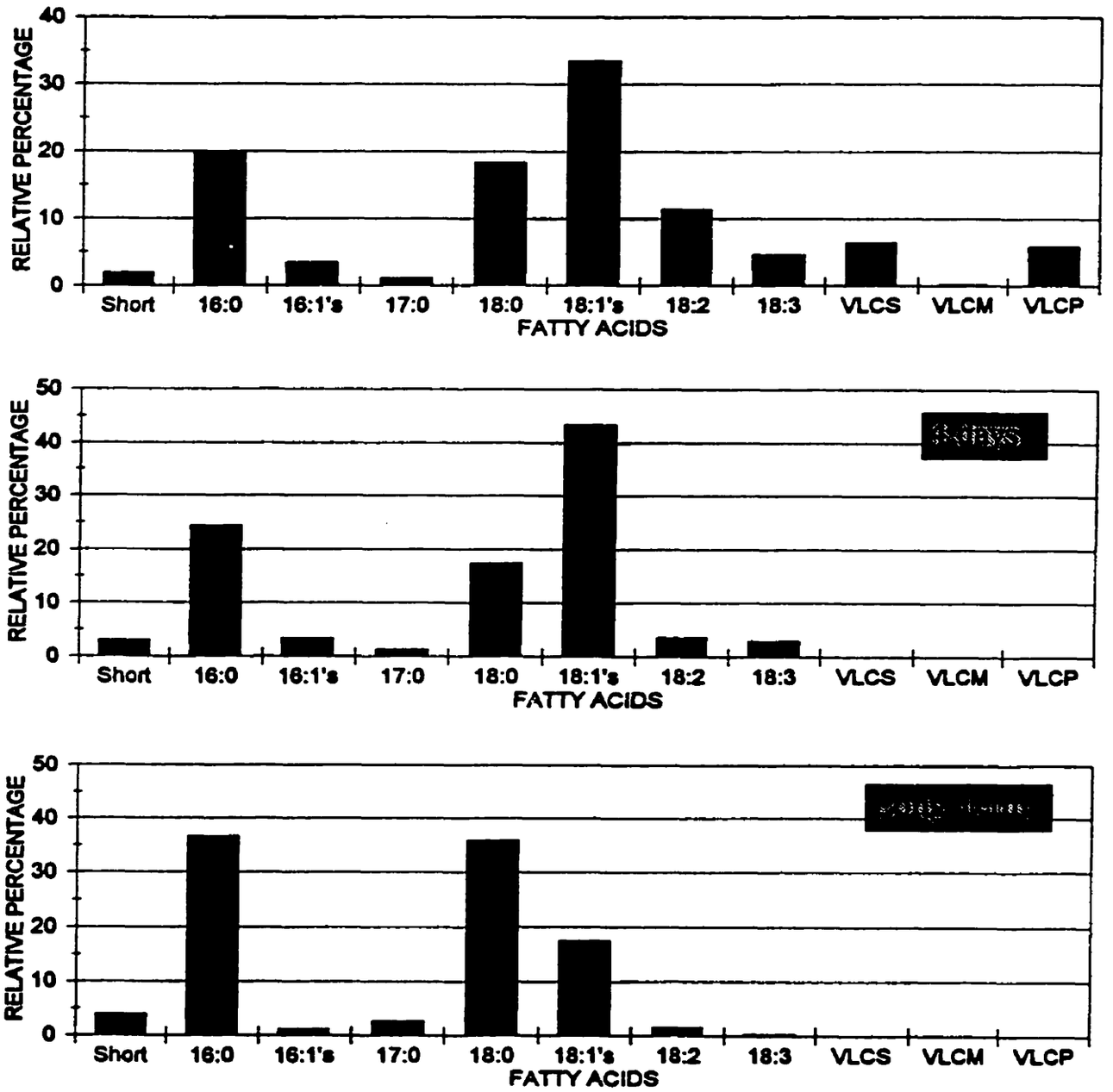


Figure E-5. Bar graphs comparing the fatty acid composition of uncooked false solomon's seal greens to experimental cooking residues after four days and long term decomposition.

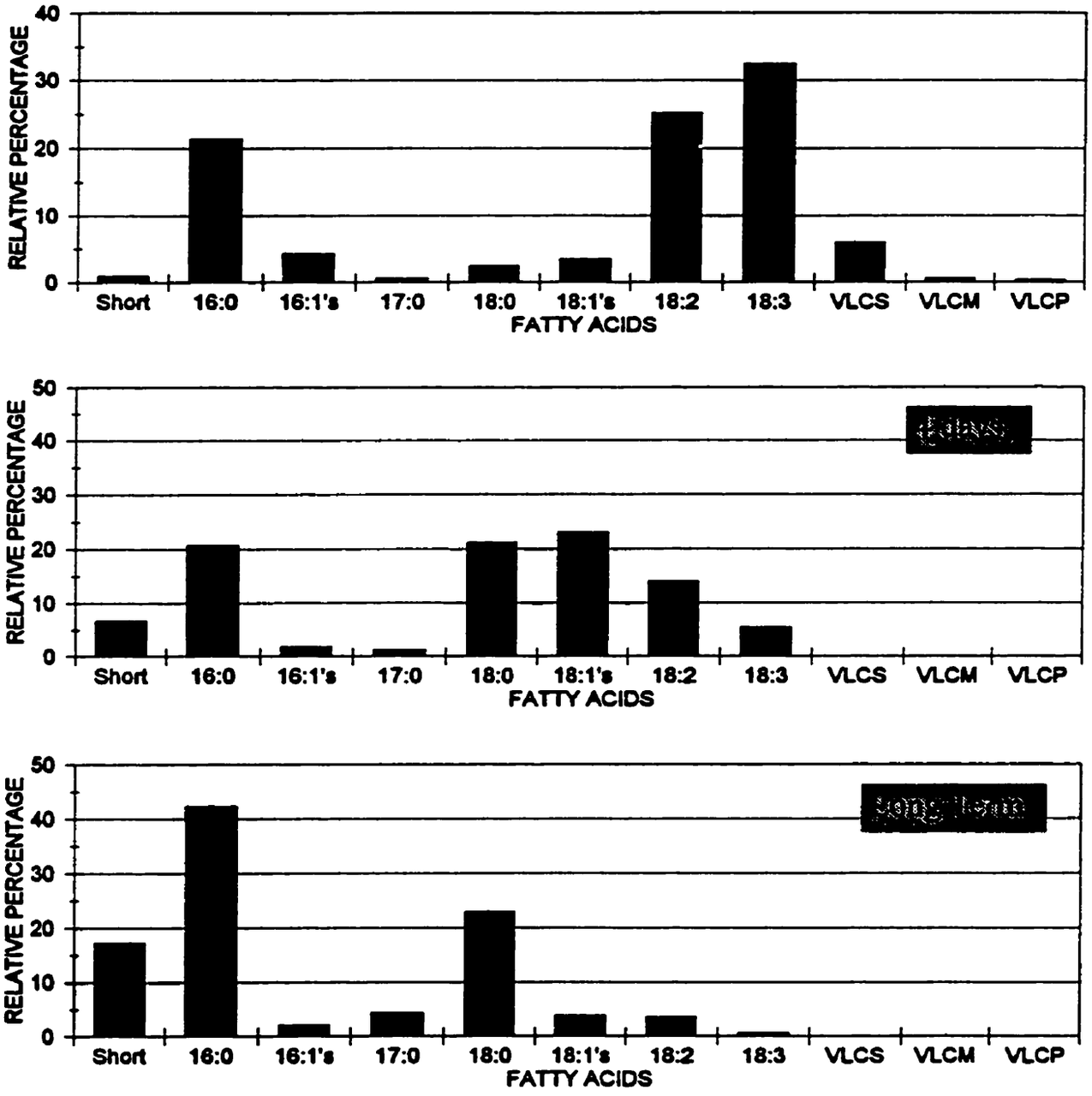


Figure E-6. Bar graphs comparing the fatty acid composition of uncooked chokecherry to experimental cooking residues after four days and long term decomposition.

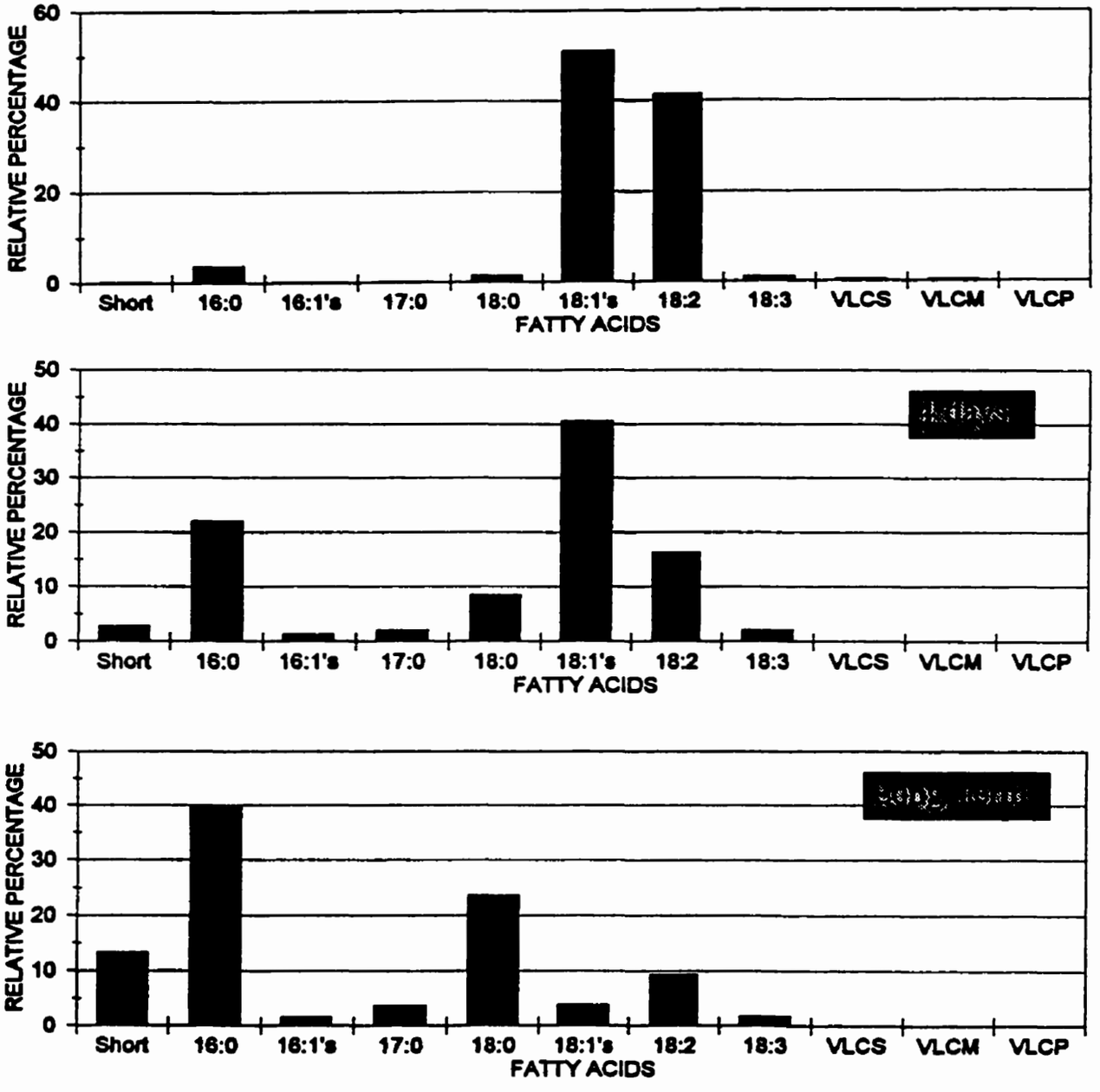


Figure E-7. Bar graphs comparing the fatty acid composition of uncooked fireweed greens to experimental cooking residues after four days and long term decomposition.

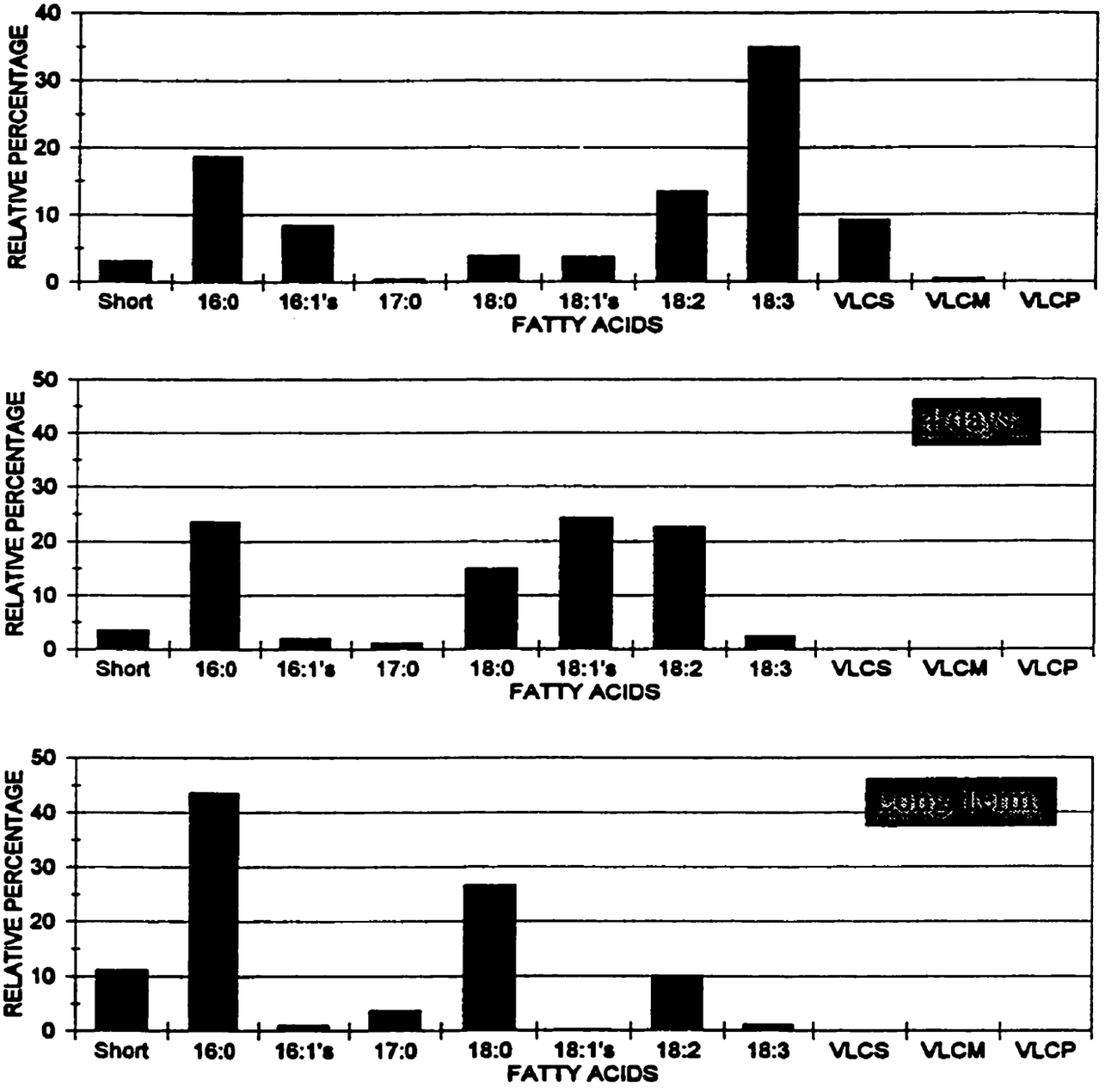


Figure E-8. Bar graphs comparing the fatty acid composition of uncooked cattail root to experimental cooking residues after four days and long term decomposition.

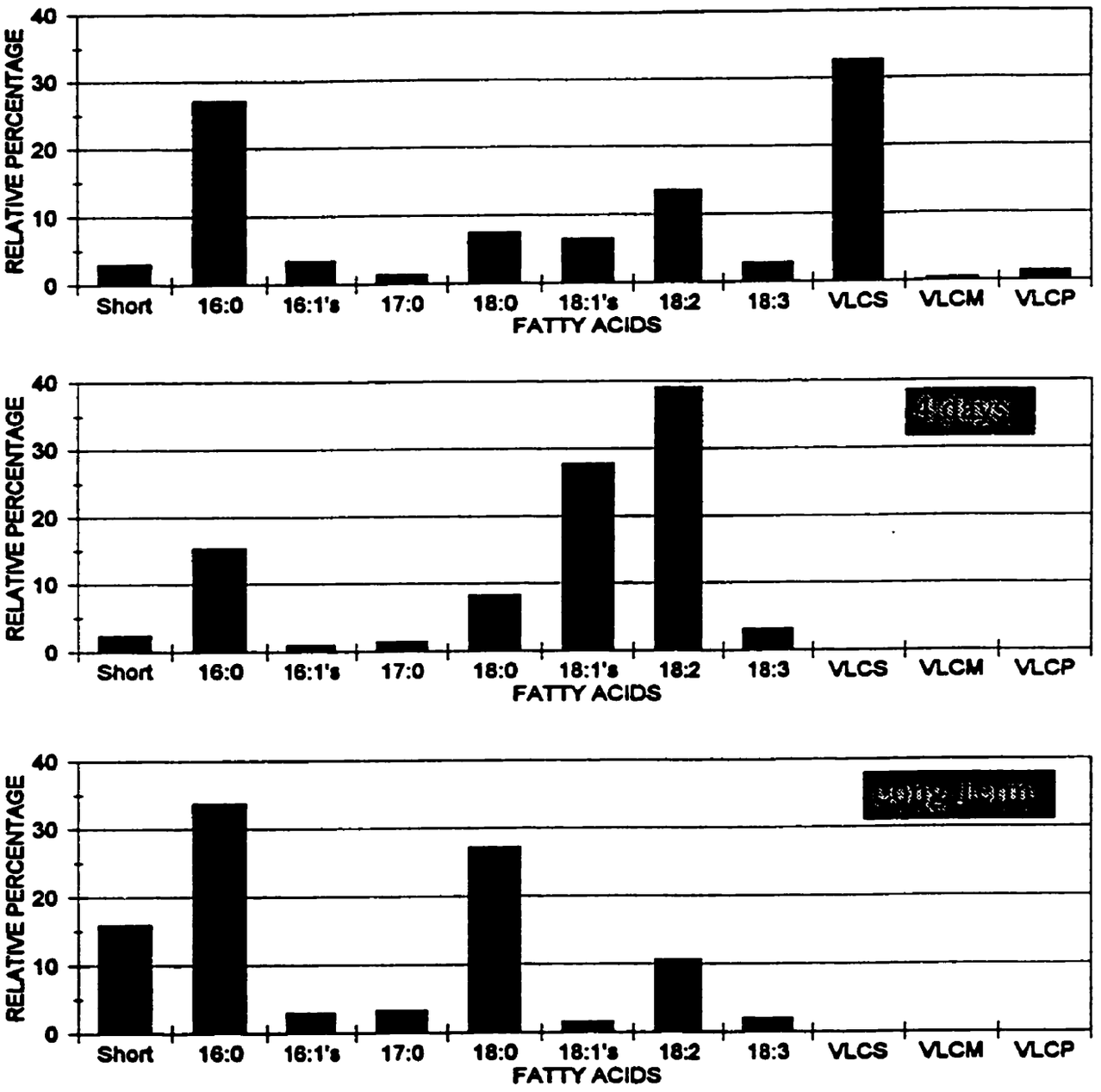


Figure E-9. Bar graphs comparing the fatty acid composition of uncooked dock seeds to experimental cooking residues after four days and long term decomposition.

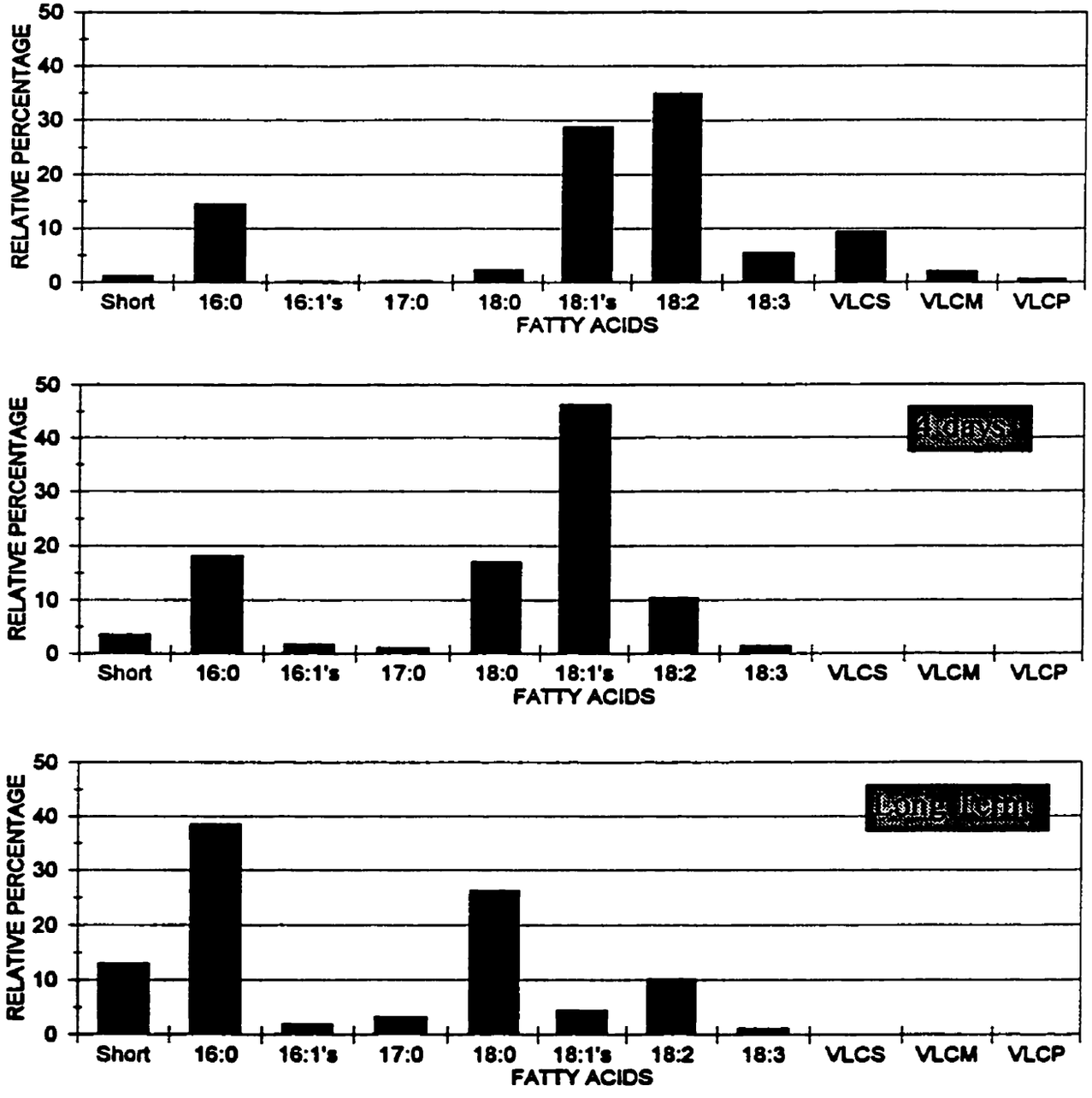


Figure E-10. Bar graphs comparing the fatty acid composition of uncooked beaver to experimental cooking residues after four days and long term decomposition.

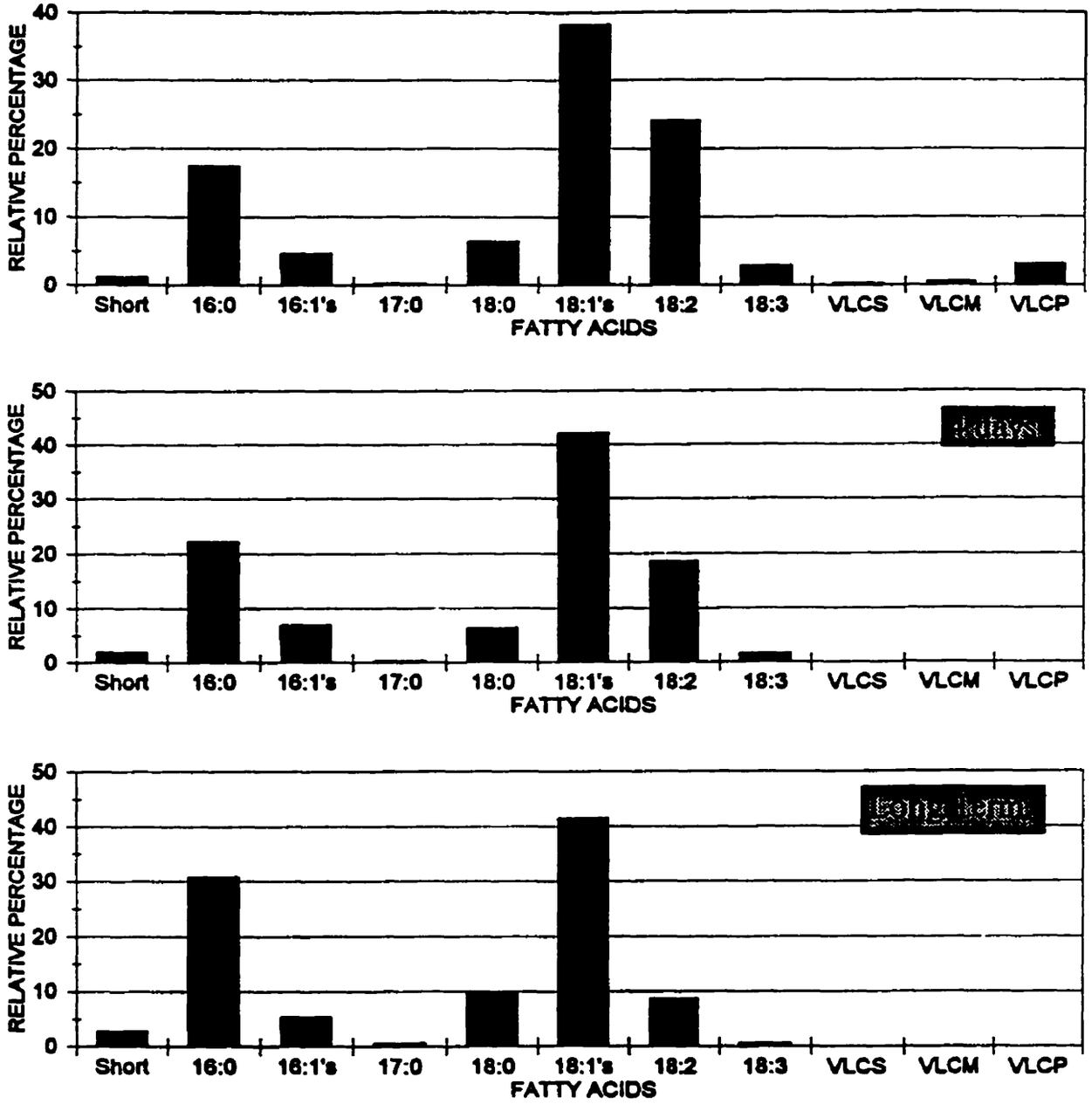


Figure E-11. Bar graphs comparing the fatty acid composition of uncooked cow bone marrow to experimental cooking residues after four days and long term decomposition.

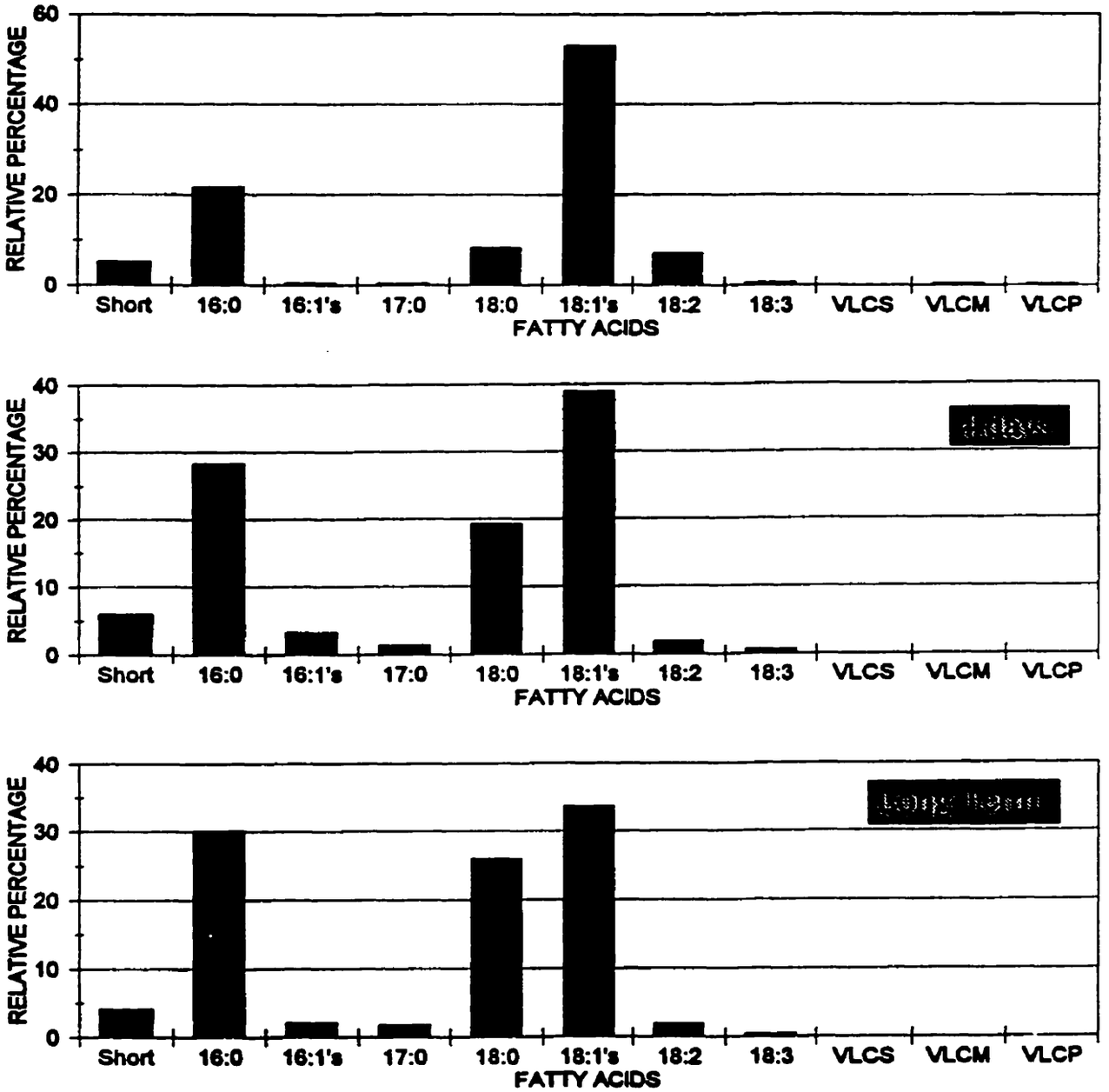


Figure E-12. Bar graphs comparing the fatty acid composition of the experimental cooking residue of lard sealant after four days and long term decomposition.

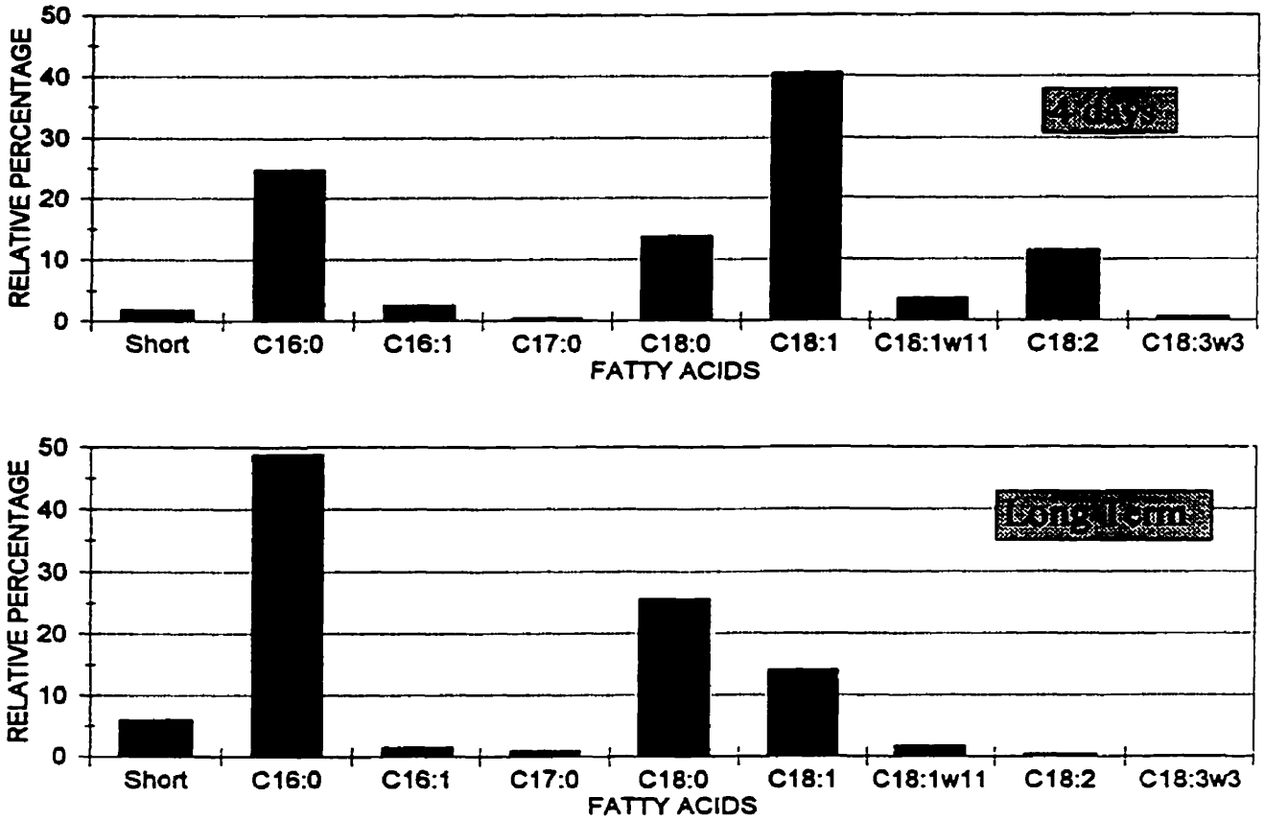


Figure E-13. Bar graphs comparing the fatty acid composition of the experimental cooking residue of pike after four days and long term decomposition.

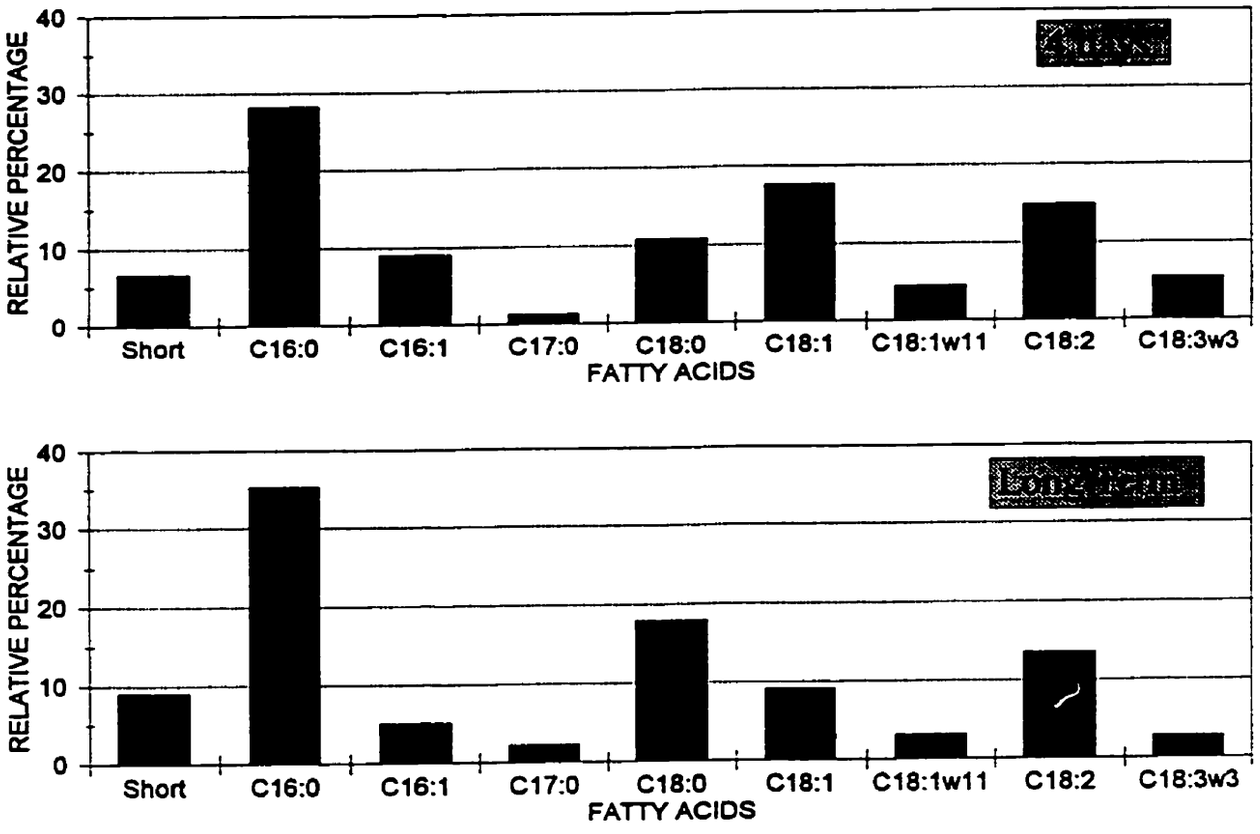


Figure E-14. Bar graphs comparing the fatty acid composition of the experimental cooking residue of bison and corn after four days and long term decomposition.

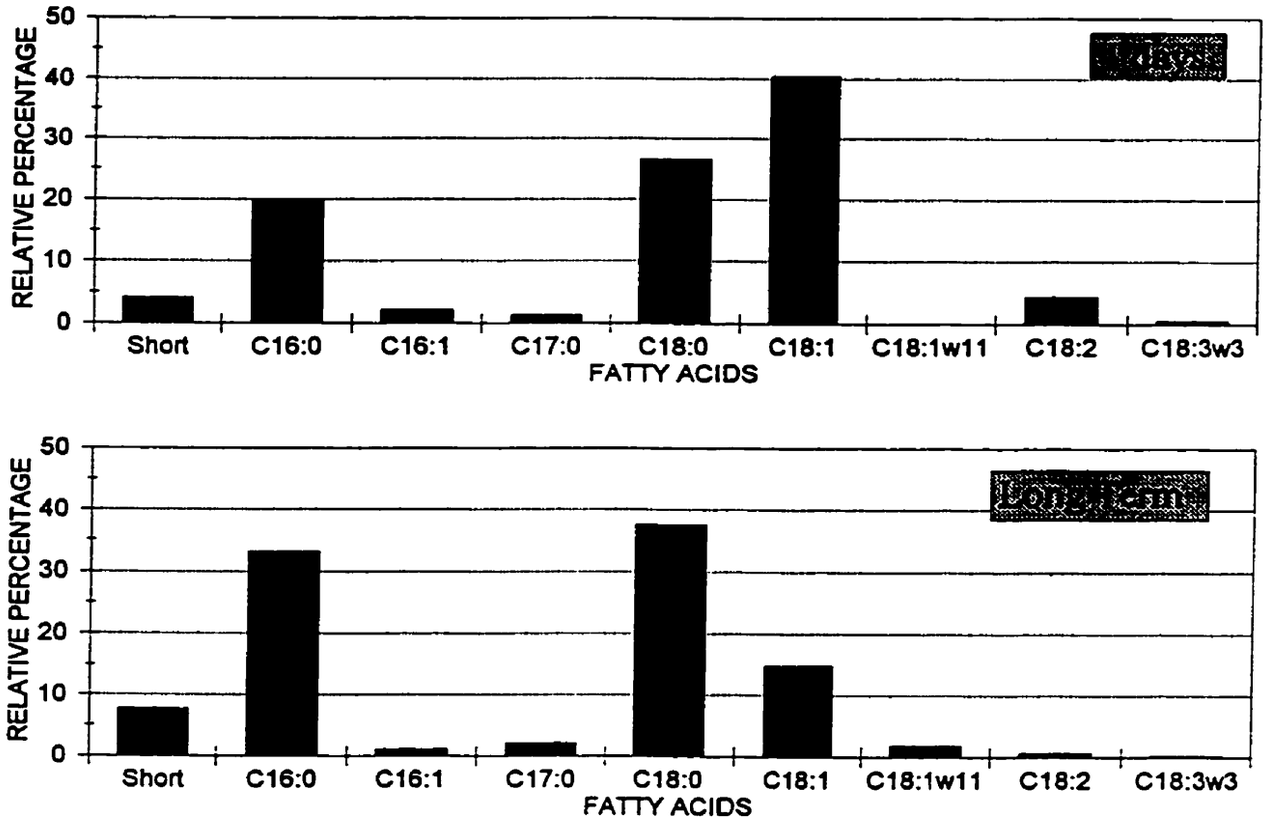


Figure E-15. Bar graphs comparing the fatty acid composition of the experimental cooking residue of bison and chokecherry after four days and long term decomposition.

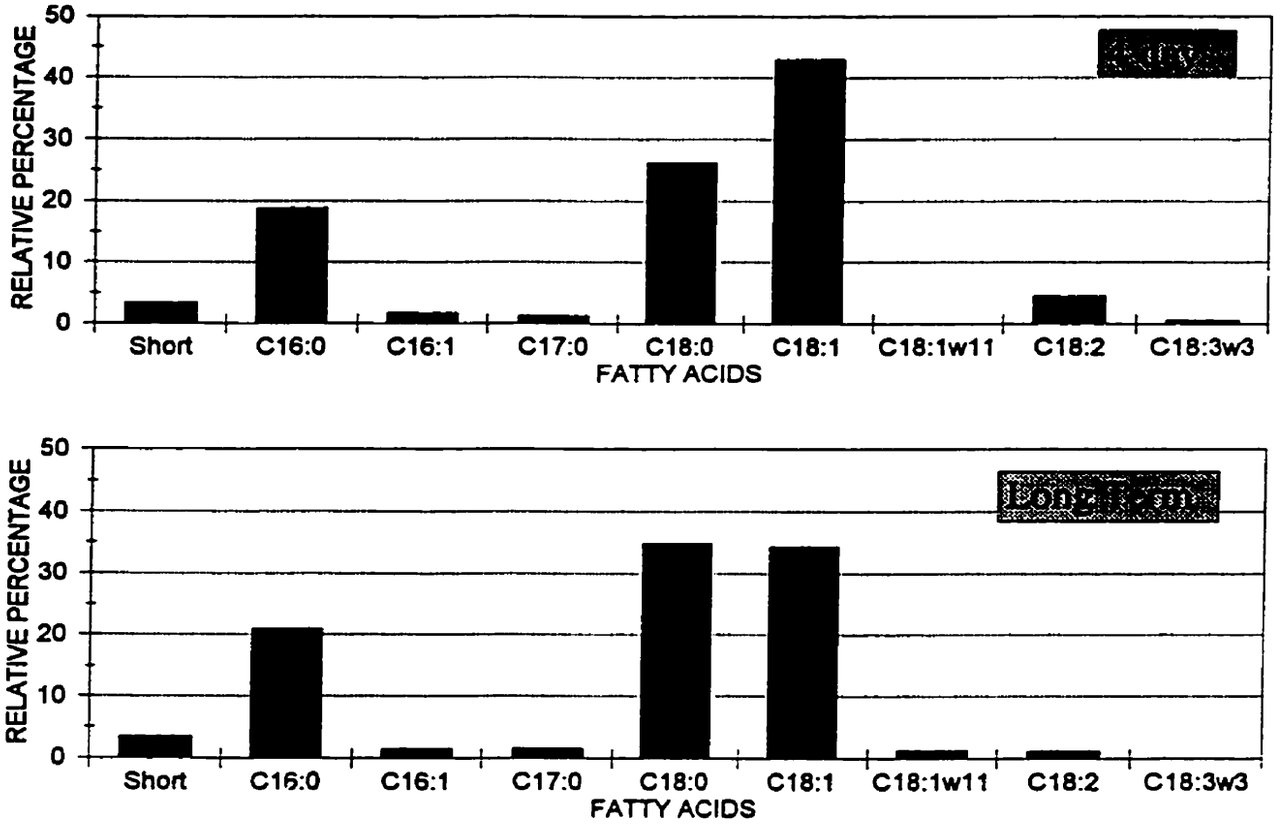


Figure E-16. Bar graphs comparing the fatty acid composition of the experimental cooking residue of deer and fireweed after four days and long term decomposition.

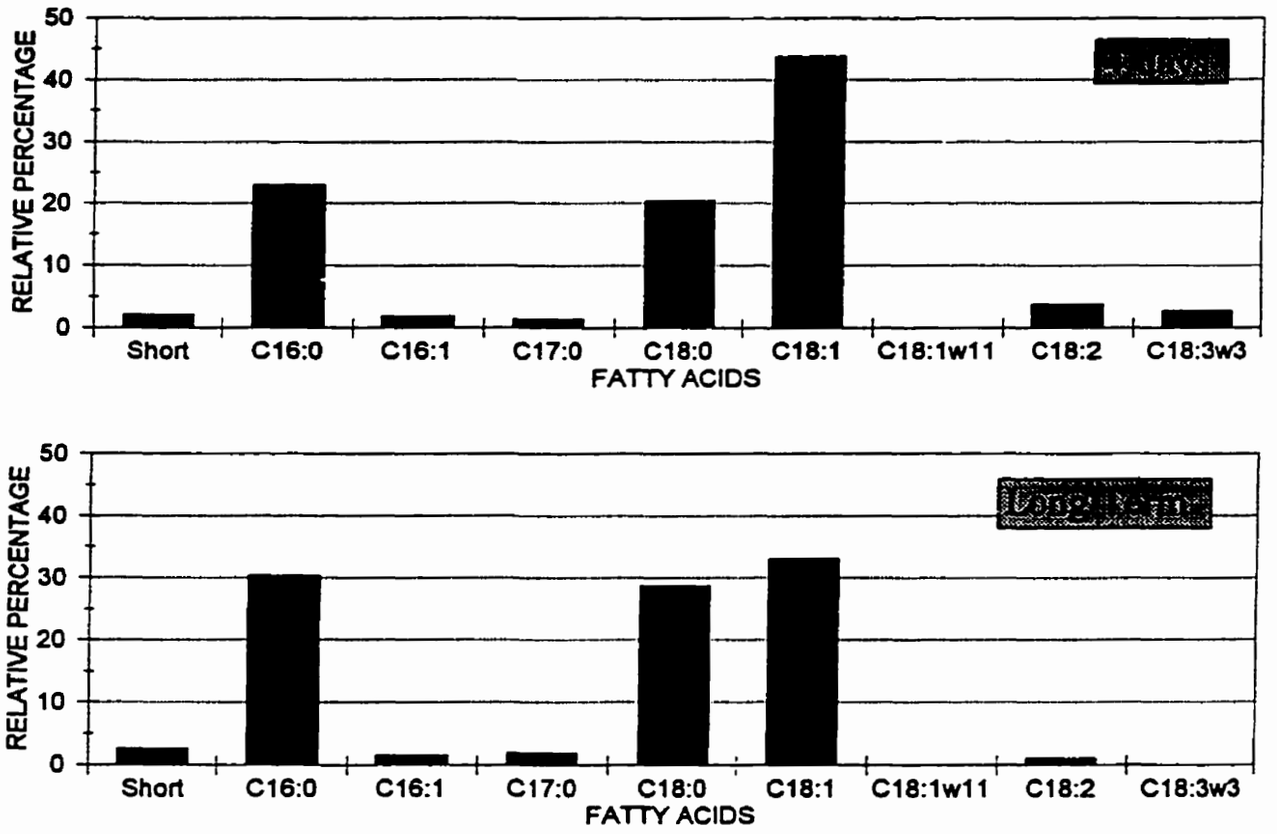


Figure E-17. Bar graphs comparing the fatty acid composition of the experimental cooking residue of saskatoon and prairie turnip after four days and long term decomposition.

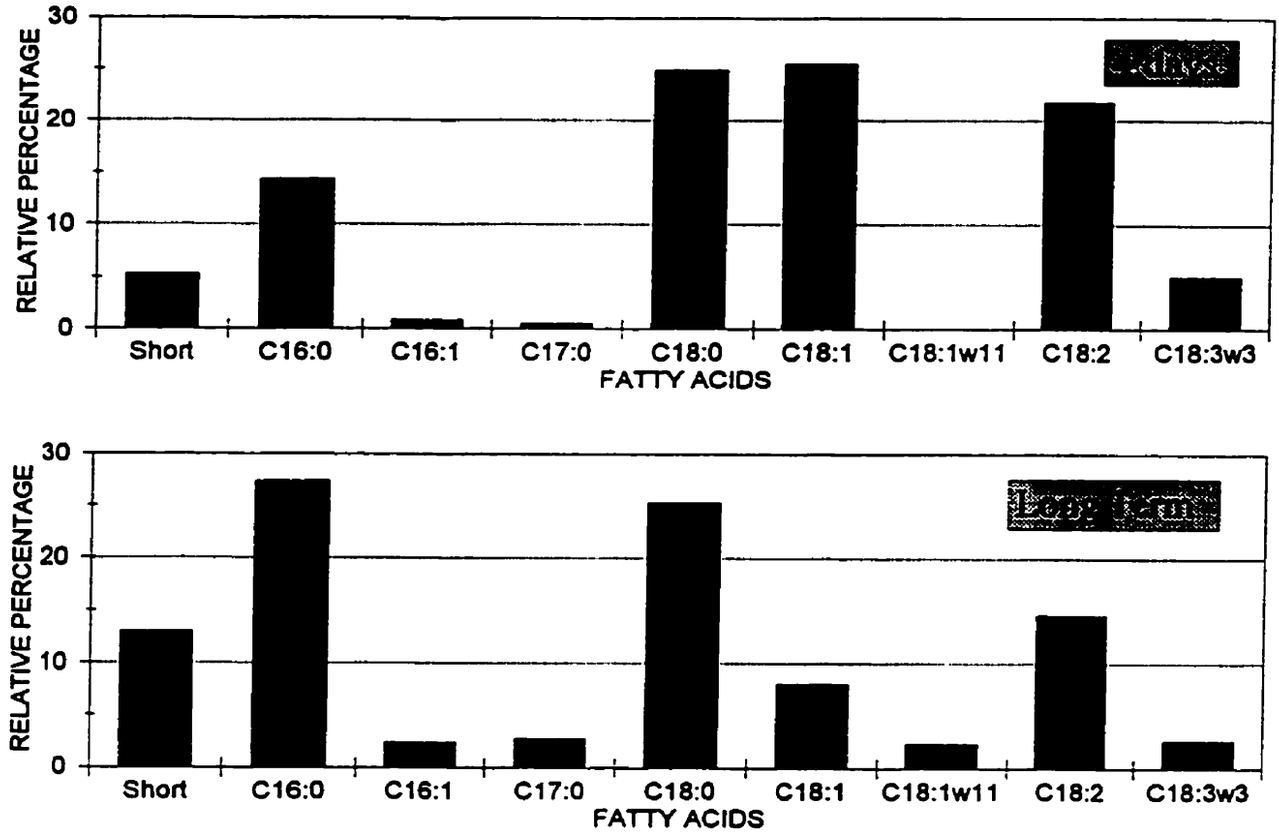
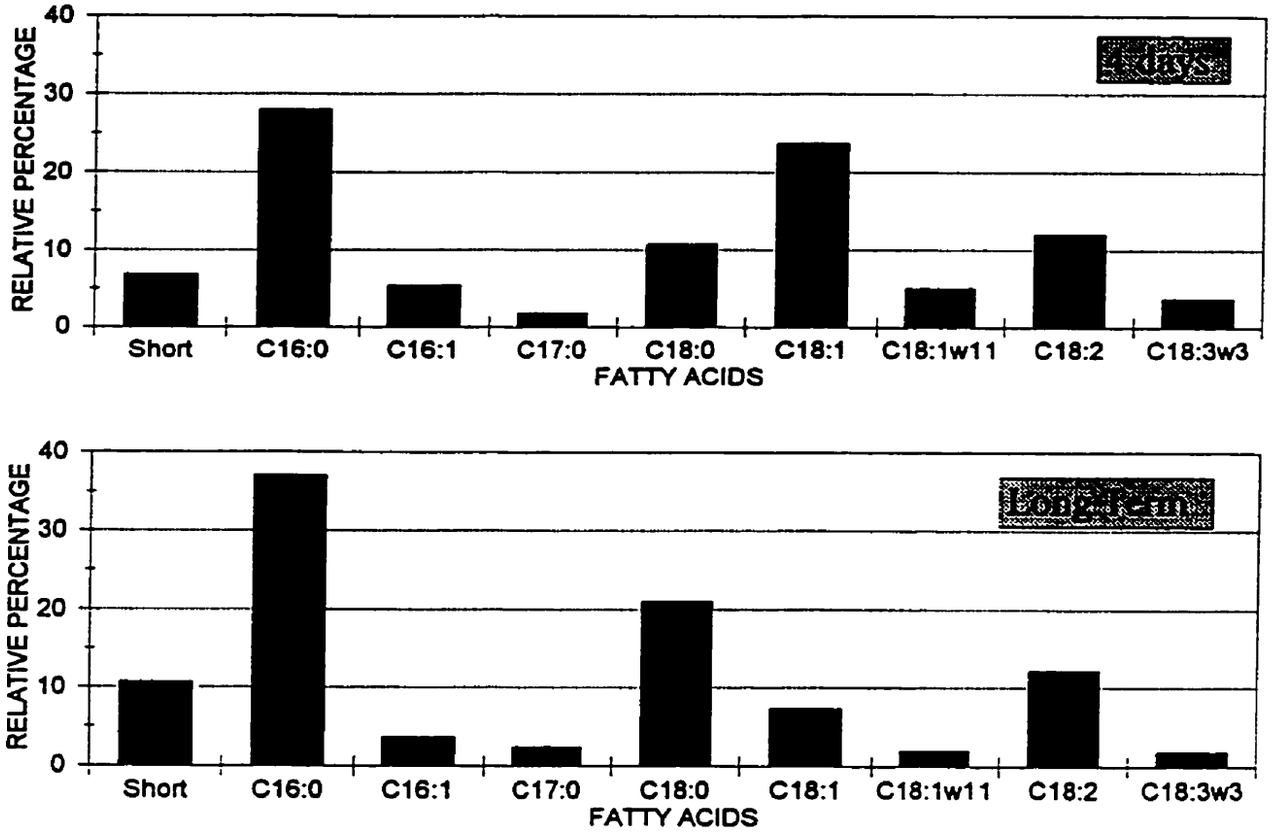


Figure E-18. Bar graphs comparing the fatty acid composition of the experimental cooking residue of pike and chokecherry after four days and long term decomposition.



APPENDIX F

Table of the fatty acid composition of archaeological vessel residues in groups produced by hierarchical cluster analysis.

CLUSTER A
SUBCLUSTER I

Cluster A1	12:0	14:0	15:0	16:0	16:1	17:0	18:0	18:1w9	18:1w11	18:2
Sand1a	0.47	3.79	1.35	42.24	0.25	3.12	39.58	7.29	0.00	1.90
Low2b	0.28	2.26	0.92	41.40	0.26	3.75	44.84	4.42	1.38	0.48
Low8a	0.89	3.33	1.58	40.53	0.34	3.82	43.64	3.97	1.29	0.61
Mork6	0.44	2.83	1.13	40.66	0.36	3.17	45.56	4.07	1.07	0.71
Mork8	0.89	3.51	1.38	40.73	0.54	3.43	39.91	7.37	1.67	0.59
Mork9	0.82	3.29	1.29	42.83	0.28	3.46	41.07	4.72	1.68	0.56
LkMid5	0.83	4.72	2.00	42.02	0.47	3.80	41.53	2.92	1.11	0.59
LkMid6	0.69	3.63	1.27	41.42	0.26	3.67	45.55	2.43	0.63	0.45
LkMid8	0.87	3.84	1.60	41.00	1.39	3.66	39.71	6.12	0.00	1.82
LkMid12	0.76	4.60	1.64	40.39	0.50	3.66	44.06	3.23	0.73	0.43
LkMid16	0.32	4.25	1.41	38.15	0.61	3.29	40.77	9.10	1.56	0.56
Hartley4	0.10	3.17	1.12	41.11	0.33	3.17	43.06	5.58	1.72	0.66
Bush9	0.28	2.80	2.17	38.91	1.06	3.96	40.55	4.59	2.93	2.76
Garratt7	0.79	4.10	1.31	39.56	0.56	3.64	41.67	7.59	0.00	0.78
LngJn6	0.40	3.93	1.34	40.31	0.32	3.43	40.33	7.82	1.62	0.49
LngJn9	0.00	3.86	1.33	43.72	0.34	3.38	40.88	4.99	1.05	0.45
LngJn12	0.19	4.22	1.27	38.84	0.31	3.18	42.72	6.93	1.89	0.46
LngJn13	0.37	4.15	1.14	41.01	0.60	3.35	40.43	7.25	1.11	0.57
LngJn14	0.29	4.67	1.17	40.24	0.59	2.95	38.60	9.30	1.07	1.12
Mean	0.51	3.73	1.39	40.79	0.49	3.47	41.81	5.77	1.18	0.84
Std. Dev.	0.29	0.67	0.30	1.37	0.29	0.28	2.10	2.06	0.72	0.63
Count	19	19	19	19	19	19	19	19	19	19

Cluster A2	12:0	14:0	15:0	16:0	16:1	17:0	18:0	18:1w9	18:1w11	18:2
Sand1b	0.44	2.78	1.51	39.04	0.00	3.61	43.42	7.26	0.00	1.94
Sand8	0.00	2.08	1.08	37.52	0.41	3.79	48.56	5.84	0.00	0.72
Sand11	0.08	2.03	1.15	39.07	0.28	4.08	44.68	7.98	0.00	0.65
Low5a	0.52	3.38	1.53	37.56	0.50	3.71	45.57	5.50	0.00	1.72
Low9a	2.31	5.83	1.93	34.67	0.75	3.76	43.62	5.68	0.00	1.46
Low10b	0.83	4.15	2.96	36.55	0.78	4.43	42.21	7.57	0.00	0.51
Low11b	0.54	3.51	1.58	37.09	0.45	3.42	44.62	7.97	0.00	0.83
Low13a	3.91	5.94	2.17	36.70	0.00	3.41	41.55	4.74	0.00	1.59
Low14b	1.05	3.76	1.29	37.96	0.24	3.35	46.37	4.71	0.90	0.39
Mork5	1.35	4.05	1.55	37.77	0.00	3.99	48.02	2.08	0.29	0.90
Mork10	1.48	3.13	1.36	37.66	0.25	3.34	47.40	3.94	0.63	0.79
Mork12	3.18	3.82	1.52	37.83	0.32	3.30	45.64	2.50	0.74	1.15
Mork13	3.17	3.92	2.23	35.87	0.87	3.97	43.48	5.47	0.00	1.03
Ross2	2.19	3.88	1.13	38.86	0.58	3.75	45.05	3.05	0.79	0.73
Ross5	0.45	3.40	1.39	37.29	0.24	3.38	43.70	7.79	1.65	0.71
Ross9	0.70	4.33	1.94	34.99	0.61	3.24	47.15	5.39	1.23	0.42
Ross12	0.20	2.57	1.20	38.37	0.20	3.78	48.66	3.75	0.85	0.42
LkMid1	0.18	3.50	1.22	38.38	0.20	3.45	49.45	3.46	0.00	0.16
LkMid10	1.06	3.95	2.51	34.42	0.91	4.34	45.21	5.04	1.49	1.08
LkMid14	0.23	2.95	1.17	38.66	0.18	3.49	49.28	2.90	0.85	0.28
LkMid15	0.27	2.99	1.16	38.17	0.79	3.40	46.70	4.12	1.80	0.60
Stott8	0.15	2.13	0.91	37.71	0.34	3.58	47.63	4.71	1.76	1.09
Stott11	0.22	2.59	1.03	37.33	0.35	3.29	44.97	8.02	1.52	0.68
Stott13	0.11	2.26	0.82	38.43	0.19	3.29	48.25	4.12	1.61	0.92

Stott15	0.39	1.88	1.09	39.41	0.25	3.90	47.34	3.55	1.55	0.65
Hartley2	0.00	1.65	0.98	33.11	0.99	3.67	47.52	6.32	2.71	3.05
Hartley8	0.14	2.16	0.89	40.49	0.18	3.52	48.86	2.48	0.76	0.53
Bush14	0.09	2.72	1.11	37.49	0.44	3.26	50.29	2.90	1.20	0.49
LngJn1	1.39	3.81	1.43	34.49	0.92	3.48	45.59	7.59	0.00	1.28
LngJn2	0.64	3.83	1.28	36.81	0.28	3.63	47.00	5.23	0.98	0.33
LngJn4	0.74	3.83	1.36	38.21	0.00	3.55	45.64	6.37	0.00	0.30
LngJn5	0.35	4.74	1.05	36.89	0.22	3.25	45.54	5.78	1.64	0.53
LngJn8	1.08	5.30	1.64	37.95	0.00	3.46	45.25	4.98	0.00	0.34
Sjovold1	0.30	2.26	0.81	37.11	0.25	3.25	44.91	6.44	1.50	3.17
Lckprt3	0.09	3.59	0.90	37.89	0.81	2.85	45.27	5.49	2.47	0.63
Lvstrm2	0.83	3.50	1.01	36.67	0.64	4.41	46.45	5.39	0.00	1.10
Mean	0.85	3.39	1.39	37.34	0.40	3.59	46.13	5.17	0.80	0.92
Std. Dev.	0.97	1.05	0.49	1.53	0.30	0.35	2.08	1.72	0.80	0.68
Count	36	36	36	36	36	36	36	36	36	36

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
LkMid13	0.20	2.51	0.84	45.86	0.16	3.46	44.48	1.41	0.70	0.38

Cluster A3	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Low1b	0.71	4.23	1.47	44.02	0.36	3.32	39.00	6.29	0.00	0.60
Low3b	1.22	4.48	1.91	44.59	0.65	3.66	38.82	4.67	0.00	0.00
Low4b	0.52	3.69	2.04	45.70	0.28	3.63	36.16	7.19	0.00	0.79
Mork7	1.71	4.38	1.69	46.69	0.00	3.22	38.13	2.78	0.72	0.67
LkMid4	1.36	6.72	2.38	42.31	0.69	3.60	37.53	4.70	0.00	0.71
LkMid11	0.46	3.93	1.57	45.65	0.62	3.56	38.88	4.48	0.00	0.86
LngJn10	0.79	5.45	1.76	45.77	0.00	3.17	32.95	9.73	0.00	0.39
Lckprt8	0.28	4.03	0.98	42.75	3.07	2.53	35.15	7.25	3.03	0.94
Mean	0.88	4.61	1.72	44.69	0.71	3.34	37.08	5.89	0.47	0.62
Std. Dev.	0.50	1.00	0.42	1.56	0.99	0.38	2.17	2.17	1.06	0.30
Count	8	8	8	8	8	8	8	8	8	8

Cluster A4	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand5a	0.00	2.70	0.65	33.06	0.00	3.13	55.51	2.48	1.43	1.04
Sand9	0.08	2.34	0.80	36.10	0.32	3.68	50.20	4.86	0.82	0.80
Sand10a	0.12	1.84	0.83	33.40	0.00	3.70	52.92	5.60	0.90	0.69
Low7a	0.46	2.99	1.32	34.20	0.38	3.39	50.91	5.97	0.00	0.38
Ross10	0.46	2.28	1.73	29.73	0.22	3.45	56.30	4.27	1.16	0.39
Ross13	0.76	2.90	1.05	34.08	0.39	3.85	51.56	3.37	0.91	1.14
Stott5	0.30	2.08	1.48	30.29	0.62	3.81	52.40	7.06	0.00	1.96
Stott9	0.07	2.13	0.97	35.34	0.14	3.35	50.73	4.65	2.04	0.59
Hartley5	0.00	1.78	0.82	32.02	0.52	3.20	53.93	5.38	1.22	1.12
HSI1	0.00	2.08	1.49	33.37	0.00	4.78	52.58	3.92	0.00	1.77
HSI2	0.00	1.97	0.65	30.70	0.00	3.25	53.70	6.85	1.14	1.74
Bush1	0.46	3.53	1.12	32.37	0.23	3.82	55.59	2.15	0.37	0.35
Bush3	0.96	2.67	1.85	35.03	0.74	5.07	51.27	1.62	0.40	0.38
Lebret3	0.00	0.89	0.58	34.37	0.00	3.32	54.55	4.26	1.53	0.51
LngJn7	0.20	3.43	0.93	35.50	0.00	3.03	51.24	4.04	1.12	0.52
LngJn11	0.73	2.98	1.67	31.08	0.00	4.71	56.91	1.27	0.32	0.32
Garratt1	0.83	2.49	0.89	33.84	0.43	3.64	51.03	6.40	0.00	0.45
Garratt3	0.64	4.12	1.05	30.75	0.42	3.25	52.82	5.22	1.16	0.57

Garratt6	0.86	4.49	1.46	35.05	0.76	3.83	49.21	3.47	0.00	0.86
Garratt12	0.67	3.68	1.29	34.29	0.51	4.09	50.11	4.64	0.00	0.72
Garratt13	0.76	3.03	0.98	33.36	0.41	3.76	52.94	4.09	0.00	0.67
Mean	0.40	2.69	1.12	33.24	0.29	3.72	52.69	4.36	0.69	0.81
Std. Dev.	0.34	0.85	0.38	1.86	0.26	0.56	2.16	1.61	0.63	0.49
Count	21	21	21	21	21	21	21	21	21	21

Cluster A5	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand10b	0.15	3.72	0.80	28.76	0.23	3.11	49.04	11.85	1.73	0.61
Stott10	0.23	2.41	1.03	31.68	0.29	3.12	48.66	10.08	1.63	0.86
Stott14	0.00	2.76	2.91	28.33	1.08	6.06	48.81	6.05	0.00	4.00
Stott16	0.00	1.91	1.55	30.51	0.63	4.09	50.57	9.95	0.00	0.80
Bush13	0.73	3.25	2.02	29.38	1.67	4.20	49.31	8.28	0.00	1.15
Sjovold2	0.42	2.36	1.40	32.63	1.04	4.37	46.76	10.21	0.00	0.81
Garratt8	0.37	2.76	1.01	33.91	0.38	3.58	47.07	10.38	0.00	0.54
Lvstrm1	1.23	3.04	1.40	25.60	0.73	5.54	52.91	7.81	0.00	1.74
Mean	0.39	2.78	1.52	30.10	0.76	4.26	49.14	9.33	0.42	1.31
Std. Dev.	0.41	0.57	0.68	2.65	0.49	1.07	1.95	1.83	0.78	1.15
Count	8	8	8	8	8	8	8	8	8	8

SUBCLUSTER II

Cluster A6	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand2	0.20	4.02	1.16	39.62	0.58	3.16	37.21	13.59	0.00	0.47
Sand7	2.29	4.21	3.09	36.06	0.00	3.65	32.91	16.55	0.00	1.23
Low6	0.34	3.63	1.29	39.49	0.79	3.22	37.15	12.09	1.60	0.40
Ross7	0.45	4.18	1.58	40.05	0.70	3.14	36.13	11.34	1.93	0.51
Lebret8	0.00	3.33	1.33	38.55	1.18	2.81	35.85	11.89	0.00	5.06
Hartley1	0.28	2.05	0.95	39.65	0.88	3.43	36.22	13.67	0.00	2.88
Sjovold3	0.87	4.12	1.19	36.42	0.85	3.30	34.57	18.07	0.00	0.60
Bush2	0.51	3.53	0.92	41.96	0.71	2.70	35.67	13.45	0.00	0.56
Bush12	0.13	3.38	1.15	34.27	0.96	2.89	35.39	18.32	2.89	0.62
Mean	0.56	3.60	1.41	38.45	0.74	3.14	35.68	14.33	0.71	1.37
Std. Dev.	0.70	0.68	0.66	2.40	0.33	0.30	1.32	2.66	1.12	1.59
Count	9	9	9	9	9	9	9	9	9	9

Cluster A7	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Stott1	0.00	2.68	1.35	33.10	0.57	3.11	39.98	15.11	2.95	1.14
Stott3	0.18	3.44	1.29	35.94	0.38	3.17	40.43	12.72	0.00	2.44
Bush4	0.18	2.67	0.85	31.13	0.72	2.84	42.97	18.11	0.00	0.53
Bush7	0.21	3.03	1.24	34.38	1.36	3.58	41.08	14.64	0.00	0.48
Bush11	0.09	2.11	0.81	32.44	0.39	3.37	44.28	16.11	0.00	0.40
Bush19	0.13	2.90	1.20	31.23	0.72	3.19	41.26	18.80	0.00	0.57
Lckprt1	0.08	2.86	0.86	33.04	2.30	2.82	39.48	14.58	3.32	0.66
Lckprt4	0.13	3.93	0.84	35.50	0.46	2.76	41.96	10.67	2.94	0.81
Mean	0.12	2.95	1.05	33.34	0.86	3.11	41.43	15.09	1.15	0.88
Std. Dev.	0.07	0.54	0.23	1.81	0.66	0.29	1.60	2.66	1.59	0.67
Count	8	8	8	8	8	8	8	8	8	8

Cluster A8	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Stott4	1.57	7.52	3.33	35.08	2.03	2.67	29.39	12.06	0.00	6.35
Hartley6	1.05	3.27	1.37	30.81	3.82	3.55	32.60	12.88	4.37	6.27

Hartley7	2.50	9.06	2.07	33.13	5.46	2.52	29.04	9.55	2.96	3.70
Lebret2	0.00	5.53	3.47	38.06	2.64	0.00	29.61	11.15	4.42	5.10
Lebret4	0.73	6.67	1.60	37.63	5.37	3.02	31.60	9.98	2.48	0.91
Garratt2	2.79	10.62	2.54	30.95	2.70	3.07	32.30	14.48	0.00	0.55
Mean	1.44	7.11	2.40	34.28	3.67	2.47	30.76	11.68	2.37	3.82
Std. Dev.	1.07	2.60	0.88	3.18	1.47	1.26	1.59	1.85	1.99	2.58
Count	6	6	6	6	6	6	6	6	6	6

SUBCLUSTER III

Cluster A9	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand6a	2.43	4.76	3.50	29.57	2.58	6.11	41.53	4.36	1.63	3.53
Mork11	4.99	5.92	5.14	30.06	1.39	8.52	40.25	2.02	0.00	1.71
Stott6	3.15	8.98	0.00	32.38	1.68	2.75	42.89	5.13	0.00	3.04
Mean	3.52	6.56	2.88	30.67	1.88	5.79	41.56	3.84	0.54	2.76
Std. Dev.	1.32	2.18	2.63	1.50	0.62	2.90	1.32	1.62	0.94	0.94
Count	3	3	3	3	3	3	3	3	3	3

Cluster A10	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Mork1	5.95	10.00	2.81	35.41	1.59	3.33	30.41	5.70	1.29	3.50
Mork2	3.13	6.09	1.79	38.60	0.00	2.89	36.97	6.66	1.06	2.81
Mork14	5.10	8.77	2.04	34.96	0.00	2.72	36.37	7.10	0.89	2.06
Ross3	2.96	5.34	4.12	38.15	1.00	4.60	35.05	7.52	0.00	1.26
Ross4	3.91	7.90	4.79	37.11	1.38	3.40	36.71	3.53	0.54	0.73
Ross8	4.80	9.12	5.52	35.55	2.37	3.88	32.31	5.94	0.00	0.51
Stott12	3.23	11.11	6.99	36.50	1.77	0.00	37.22	2.18	0.00	1.00
Mean	4.16	8.33	4.01	36.61	1.16	2.97	35.01	5.52	0.54	1.70
Std. Dev.	1.15	2.06	1.92	1.41	0.89	1.45	2.64	1.97	0.55	1.13
Count	7	7	7	7	7	7	7	7	7	7

Cluster A11	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Bush5	4.51	15.12	3.89	30.61	0.00	4.93	34.72	3.45	0.95	1.82
Garratt11	3.47	15.28	2.42	35.17	2.08	1.84	33.90	4.15	0.00	1.69
Mean	3.99	15.20	3.16	32.89	1.04	3.38	34.31	3.80	0.47	1.75
Std. Dev.	0.73	0.12	1.04	3.22	1.47	2.19	0.58	0.49	0.67	0.09
Count	2	2	2	2	2	2	2	2	2	2

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Ross11	6.77	11.00	11.77	27.34	2.01	3.52	31.28	4.86	0.00	1.46

SUBCLUSTER IV

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand3	0.00	1.61	0.65	21.73	0.67	2.83	61.42	6.74	1.60	2.75
HSI3	0.11	0.88	0.38	22.82	0.23	2.99	59.21	11.00	0.00	2.38
HSI4	0.00	1.32	0.88	28.20	0.00	3.89	61.32	3.52	0.00	0.87
Mean	0.04	1.27	0.64	24.25	0.30	3.23	60.65	7.08	0.53	2.00
Std. Dev.	0.06	0.37	0.25	3.46	0.34	0.57	1.25	3.75	0.92	0.99
Count	3	3	3	3	3	3	3	3	3	3

CLUSTER B
SUBCLUSTER V

Cluster B1	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand4	2.87	8.62	2.46	34.03	12.32	1.78	12.01	19.79	0.00	6.12
Sand5b	4.15	8.48	2.57	29.33	12.40	2.40	13.12	24.52	0.00	3.03
CabPt15	10.59	12.06	6.07	29.90	8.81	0.00	10.86	17.60	2.79	1.33
Bush15	5.05	7.10	6.45	27.04	11.55	3.06	12.52	22.47	0.00	4.75
Mean	5.67	9.06	4.39	30.08	11.27	1.81	12.13	21.10	0.70	3.80
Std. Dev.	3.40	2.11	2.17	2.91	1.69	1.32	0.96	3.03	1.39	2.08
Count	4	4	4	4	4	4	4	4	4	4

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Hartley10	4.85	8.53	2.99	29.42	12.80	1.99	6.13	13.75	6.73	12.81

Cluster B2	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch7	2.35	8.60	3.74	31.34	4.43	0.00	11.08	22.76	4.21	11.48
Asch18	2.73	4.86	1.19	30.48	3.39	1.24	16.78	20.30	4.26	14.76
CabPt7	2.18	8.14	3.76	31.75	4.19	0.00	12.62	22.71	6.51	8.12
Lebret6	3.18	15.61	3.69	31.59	5.30	3.10	10.75	19.95	0.00	6.84
Lebret10	5.32	12.60	2.01	30.95	4.83	1.12	8.83	19.09	0.00	15.24
Lebret11	1.37	10.69	4.08	31.34	4.70	1.65	14.51	18.31	3.68	9.68
Lvstrm3	0.66	11.26	2.61	27.45	7.37	4.77	10.85	22.75	2.27	10.01
Mean	2.54	10.25	3.01	30.70	4.89	1.70	12.20	20.84	2.99	10.88
Std. Dev.	1.49	3.46	1.09	1.49	1.25	1.72	2.68	1.89	2.39	3.18
Count	7	7	7	7	7	7	7	7	7	7

Cluster B3	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
CabPt5	3.37	13.62	0.00	37.76	2.90	0.00	17.49	16.66	2.01	6.18
CabPt16	6.83	10.24	5.60	32.01	2.92	0.00	18.49	18.59	2.29	3.03
CabPt17	0.82	6.62	5.24	38.28	1.43	2.14	21.79	18.62	0.00	5.08
LkMid9	2.09	8.80	2.37	36.97	3.28	1.68	15.64	21.11	2.69	5.37
Mean	3.28	9.82	3.30	36.25	2.63	0.95	18.35	18.74	1.75	4.91
Std. Dev.	2.59	2.94	2.63	2.88	0.82	1.12	2.58	1.82	1.20	1.34
Count	4	4	4	4	4	4	4	4	4	4

Cluster B4	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch2	2.06	4.55	2.32	26.30	2.66	0.00	14.02	32.91	5.15	10.03
Asch14	5.29	6.36	2.25	24.58	4.82	0.00	10.30	30.15	5.43	10.82
CabPt6	4.25	12.67	0.00	26.95	3.37	1.09	11.14	28.25	1.93	10.36
Mean	3.87	7.86	1.52	25.94	3.61	0.36	11.82	30.44	4.17	10.40
Std. Dev.	1.65	4.26	1.32	1.22	1.10	0.63	1.95	2.34	1.95	0.40
Count	3	3	3	3	3	3	3	3	3	3

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Hartley9	5.73	13.10	2.91	23.27	5.68	1.16	9.31	23.20	8.01	7.64
Lebret9	2.53	9.44	2.21	21.92	2.81	2.22	20.55	23.34	3.48	11.50
Sjovold4	9.19	10.60	2.66	22.90	8.56	2.95	5.40	31.86	0.00	5.88

SUBCLUSTER VI

Cluster B5	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Sand6b	4.29	8.56	3.36	34.59	9.01	2.99	15.70	10.03	2.45	9.02

Ross6	4.72	13.32	8.89	37.46	9.49	2.90	13.42	6.82	0.69	2.29
CabPt13	7.92	11.11	3.92	38.42	5.19	1.37	15.19	10.45	3.56	2.86
BlkFoxIs1	10.01	13.67	6.77	33.95	2.98	2.53	13.17	11.41	0.00	5.50
LkMid2	8.53	12.53	4.51	37.15	4.16	1.94	14.33	8.33	2.46	6.06
Bush8	7.66	14.52	3.22	33.11	9.62	5.40	16.18	7.23	0.00	3.07
Mean	7.19	12.29	5.11	35.78	6.74	2.85	14.67	9.05	1.53	4.80
Std. Dev.	2.24	2.16	2.26	2.17	2.97	1.39	1.23	1.86	1.50	2.57
Count	6	6	6	6	6	6	6	6	6	6

Cluster B6	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
LkMid3	10.62	15.02	4.34	40.08	6.49	1.63	7.56	6.08	3.32	4.86
LngJn3	5.97	17.24	4.85	34.26	5.54	1.71	9.53	8.22	4.20	8.48
Garratt9	7.97	23.96	4.34	34.65	5.31	2.41	10.16	8.73	0.00	2.46
Garratt10	9.02	21.55	4.66	33.73	4.75	2.32	11.06	9.23	0.00	3.68
Mean	8.40	19.44	4.55	35.68	5.52	2.02	9.58	8.07	1.88	4.87
Std. Dev.	1.95	4.05	0.25	2.96	0.73	0.41	1.48	1.38	2.20	2.60
Count	4	4	4	4	4	4	4	4	4	4

Cluster B7	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Stott7	5.46	18.66	13.48	31.98	3.33	0.00	12.38	10.69	0.00	4.02
CabPt14	9.70	16.35	13.31	39.03	3.70	0.00	9.82	5.45	1.19	1.44
Mean	7.58	17.51	13.40	35.50	3.52	0.00	11.10	8.07	0.60	2.73
Std. Dev.	3.00	1.64	0.12	4.98	0.26	0.00	1.81	3.71	0.84	1.82
Count	2	2	2	2	2	2	2	2	2	2

Cluster B8	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Ross1	3.93	18.34	7.17	38.76	4.62	2.97	16.56	5.42	0.00	2.24
Lebret5	3.14	16.99	4.53	35.73	4.14	2.98	20.25	9.40	0.00	2.84
Garratt5	3.75	18.23	3.64	36.12	1.75	3.23	23.52	6.76	0.00	3.00
Mean	3.61	17.85	5.11	36.87	3.50	3.06	20.11	7.19	0.00	2.69
Std. Dev.	0.41	0.75	1.83	1.65	1.54	0.15	3.48	2.03	0.00	0.40
Count	3	3	3	3	3	3	3	3	3	3

Cluster B9	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Low12a	9.97	10.63	3.47	37.88	2.27	2.16	25.52	5.32	0.96	1.82
Mork3	4.52	12.23	3.82	42.08	2.25	2.19	20.13	7.22	2.79	2.77
Bush6	1.80	8.58	5.55	39.92	0.00	4.59	25.49	7.35	1.50	5.21
Garratt4	7.02	13.34	2.56	34.07	3.34	4.23	24.28	7.26	0.00	3.90
Mean	5.83	11.19	3.85	38.49	1.97	3.29	23.85	6.79	1.31	3.42
Std. Dev.	3.49	2.07	1.25	3.41	1.41	1.30	2.55	0.98	1.17	1.46
Count	4	4	4	4	4	4	4	4	4	4

SUBCLUSTER VII

Cluster B10	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Lckprt5	0.40	4.49	1.28	51.35	5.08	2.06	14.63	15.04	5.01	0.66
Lckprt6	0.24	5.58	1.14	47.63	7.09	1.97	15.04	14.43	6.47	0.42
Lckprt7	0.45	5.23	1.28	50.13	5.57	2.27	15.80	14.37	4.37	0.53
Bush10	1.17	6.11	2.22	47.14	8.67	2.70	13.82	12.58	4.45	1.14
Bush17	1.07	6.46	2.18	47.51	7.72	2.46	16.42	11.74	4.04	0.42
Mean	0.66	5.57	1.62	48.75	6.83	2.29	15.14	13.63	4.87	0.64
Std. Dev.	0.42	0.77	0.53	1.87	1.49	0.30	1.01	1.40	0.96	0.30

Count	5	5	5	5	5	5	5	5	5	5
Cluster B11	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch4	1.54	5.91	1.98	44.83	2.98	2.43	23.76	11.11	4.01	1.44
Asch5	0.82	6.08	1.79	47.10	5.83	2.35	18.79	11.67	4.33	1.24
Asch6	2.25	5.51	2.56	44.59	3.87	2.43	20.59	8.76	4.58	4.87
Asch13	2.13	5.58	2.14	45.96	5.88	1.95	18.66	9.28	3.71	4.71
Lebret12	0.50	6.55	1.25	47.93	4.85	2.86	19.25	10.91	4.77	1.14
Lckprt2	0.23	4.65	0.94	43.06	7.73	2.05	23.86	12.04	4.79	0.66
Mean	1.24	5.72	1.78	45.58	5.19	2.34	20.82	10.63	4.36	2.34
Std. Dev.	0.85	0.64	0.59	1.78	1.68	0.32	2.42	1.32	0.44	1.91
Count	6	6	6	6	6	6	6	6	6	6
	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch12	2.09	8.66	0.00	46.56	10.05	1.76	16.33	6.97	5.01	2.57
Cluster B12	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch1	1.30	4.81	2.28	41.39	7.09	2.10	18.59	12.59	6.65	3.19
Asch3	2.05	6.99	4.17	40.47	2.95	0.00	17.41	12.78	7.74	5.44
Asch10	3.11	5.98	2.58	40.00	8.14	0.00	13.26	11.44	8.64	6.84
Asch11	3.05	7.51	2.00	41.90	5.29	0.80	12.63	12.54	7.86	6.41
Asch15	3.09	8.25	2.62	41.25	7.23	1.07	13.02	14.08	5.02	4.37
Mean	2.52	6.71	2.73	41.00	6.14	0.80	14.99	12.68	7.18	5.25
Std. Dev.	0.82	1.35	0.85	0.76	2.06	0.87	2.80	0.94	1.40	1.49
Count	5	5	5	5	5	5	5	5	5	5
	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch17	0.95	5.54	2.34	40.51	13.40	1.58	11.17	13.84	7.76	2.91
Cluster B13	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
CabPt2	2.30	8.84	3.30	46.92	3.78	2.27	11.00	11.17	2.83	7.60
Lebret1	2.93	13.02	2.25	44.24	5.00	2.44	15.29	7.69	3.65	3.49
Lebret7	3.81	12.59	3.85	42.99	5.15	3.38	11.42	8.67	1.50	6.63
Mean	3.01	11.49	3.13	44.72	4.64	2.70	12.57	9.18	2.66	5.91
Std. Dev.	0.76	2.30	0.82	2.01	0.75	0.59	2.37	1.79	1.09	2.14
Count	3	3	3	3	3	3	3	3	3	3
	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch16	0.56	3.76	1.68	46.51	1.96	2.01	12.95	18.52	3.01	9.05
Cluster B14	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Asch8	0.47	8.14	1.97	53.42	4.02	2.64	19.32	6.43	2.73	0.85
Asch9	3.10	8.67	4.42	48.65	4.21	2.21	19.50	5.11	3.04	1.08
Mean	1.79	8.41	3.20	51.04	4.12	2.42	19.41	5.77	2.88	0.96
Std. Dev.	1.86	0.38	1.73	3.37	0.13	0.30	0.13	0.94	0.22	0.16
Count	2	2	2	2	2	2	2	2	2	2
	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
CabPt9	1.06	6.66	3.03	52.87	1.77	4.31	25.86	3.03	0.83	0.56
CabPt8	0.39	2.78	1.08	56.54	1.87	2.89	20.77	12.93	0.00	0.76

SUBCLUSTER VIII

	12:0	14:0	15:0	16:0	16:1	17:0	18:0	18:1w9	18:1w11	18:2
LkMid7	17.35	19.94	7.09	27.72	5.41	6.99	7.37	3.65	0.37	4.13
Bush16	5.60	28.64	7.69	17.84	9.67	2.26	11.35	14.23	0.00	2.72
Mean	11.47	24.29	7.39	22.78	7.54	4.63	9.36	8.94	0.18	3.42
Std. Dev.	8.31	6.15	0.43	6.98	3.01	3.35	2.81	7.49	0.26	0.99
Count	2	2	2	2	2	2	2	2	2	2

CLUSTER C

Cluster C1	**12:0**	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
CabPt1	6.11	9.49	1.77	21.97	2.79	0.95	9.79	38.92	0.00	8.21
CabPt3	2.75	5.17	1.28	17.81	1.82	0.42	7.00	36.55	2.25	24.96
CabPt4	1.47	2.66	0.83	16.54	2.31	0.30	6.12	38.11	2.78	28.89
CabPt11	4.09	5.85	1.23	19.31	2.57	0.37	7.39	48.13	0.00	11.05
Mean	3.60	5.79	1.28	18.90	2.37	0.51	7.58	40.43	1.26	18.28
Std. Dev.	1.99	2.82	0.39	2.33	0.42	0.30	1.57	5.23	1.47	10.18
Count	4	4	4	4	4	4	4	4	4	4

	12:0	**14:0**	**15:0**	**16:0**	**16:1**	**17:0**	**18:0**	**18:1w9**	**18:1w11**	**18:2**
Bush18	0.00	2.16	0.64	25.08	0.78	2.35	32.90	35.56	0.00	0.52

APPENDIX G

Bar graphs of the average fatty acid composition of groups produced by hierarchical cluster analysis

Figure G-1. Bar graph showing the average fatty acid composition of clusters A1 and A2.

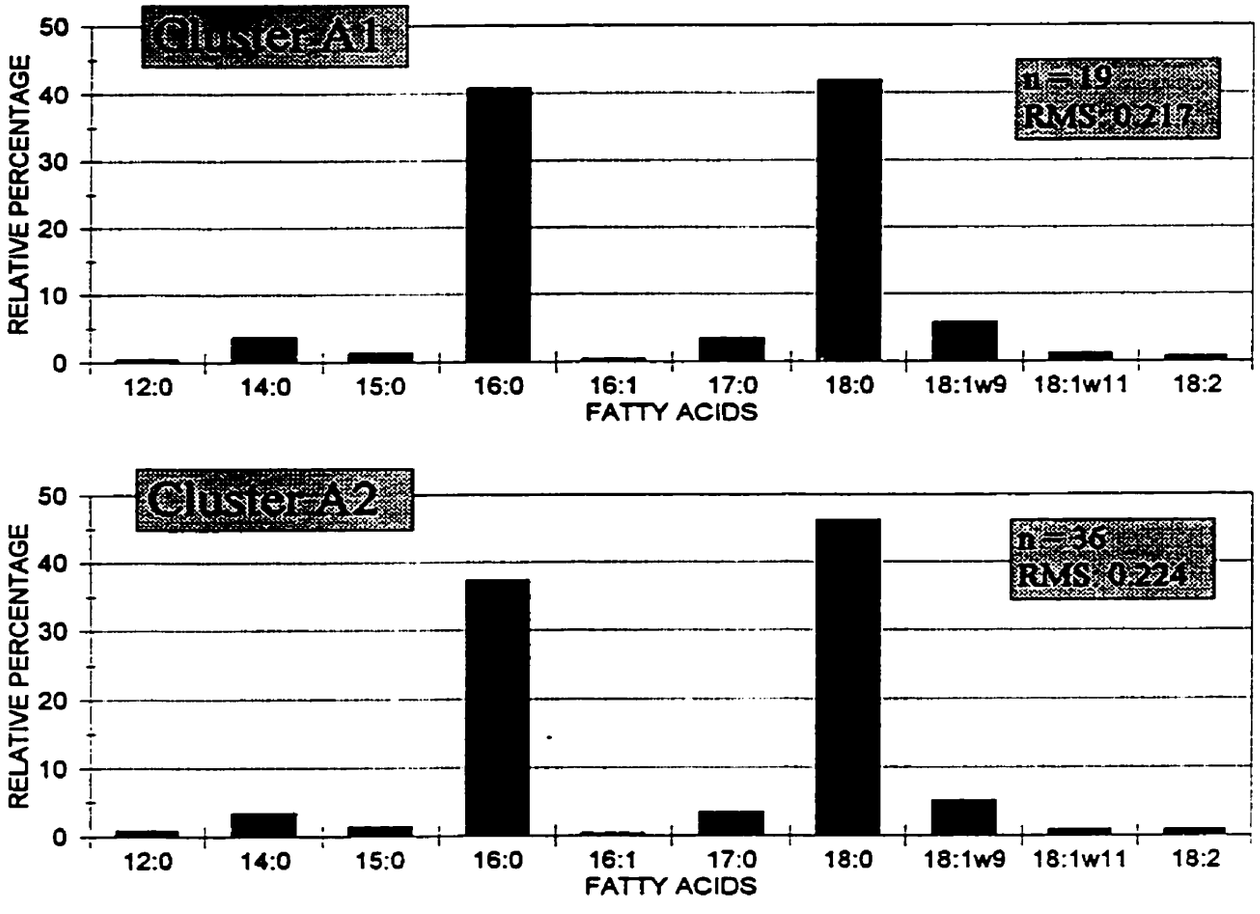


Figure G-2. Bar graph showing the average fatty acid composition of cluster A3 and the LkMid 13 residue.

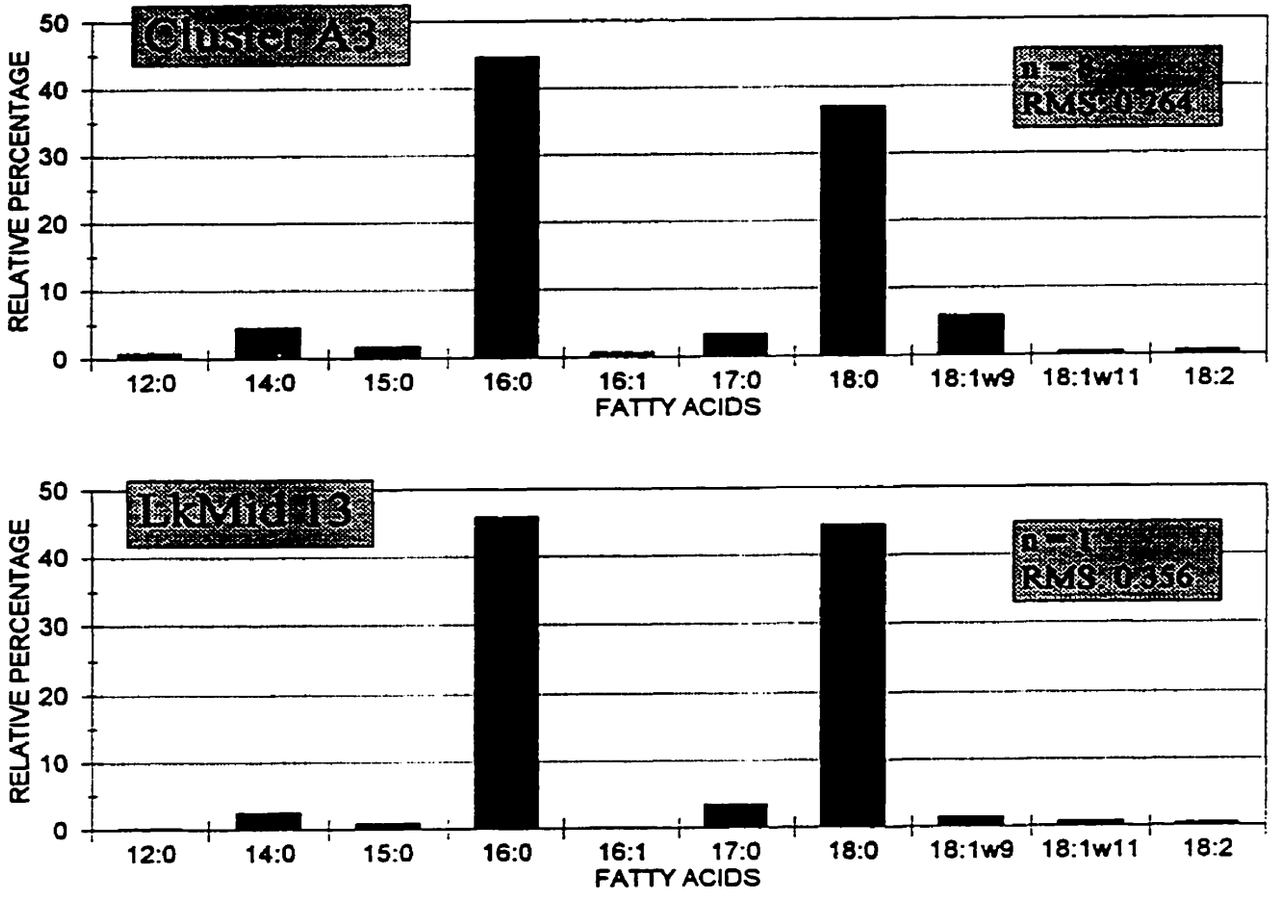


Figure G-3. Bar graph showing the average fatty acid composition of clusters A4 and A5.

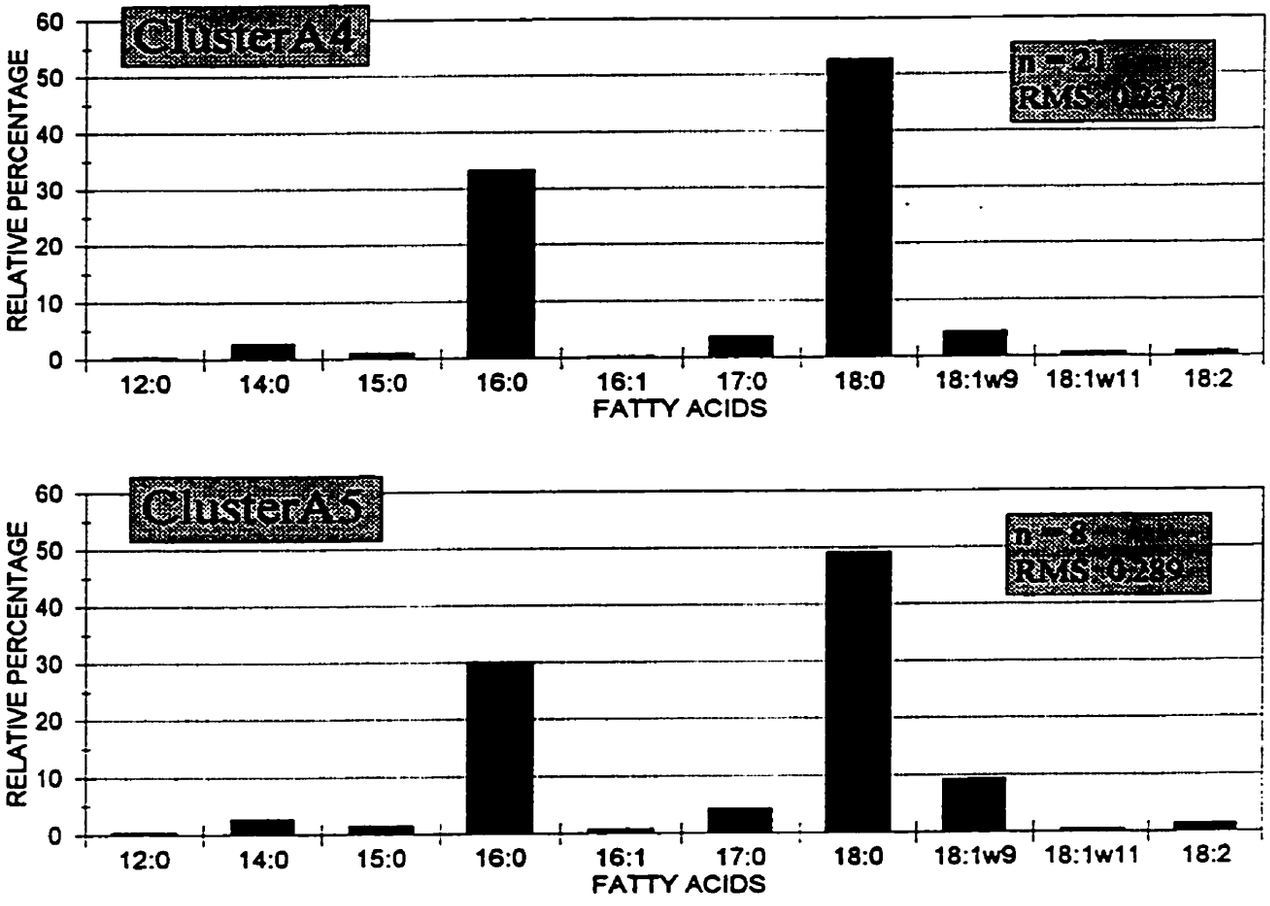


Figure G-4. Bar graph showing the average fatty acid composition of clusters A6 and A7.

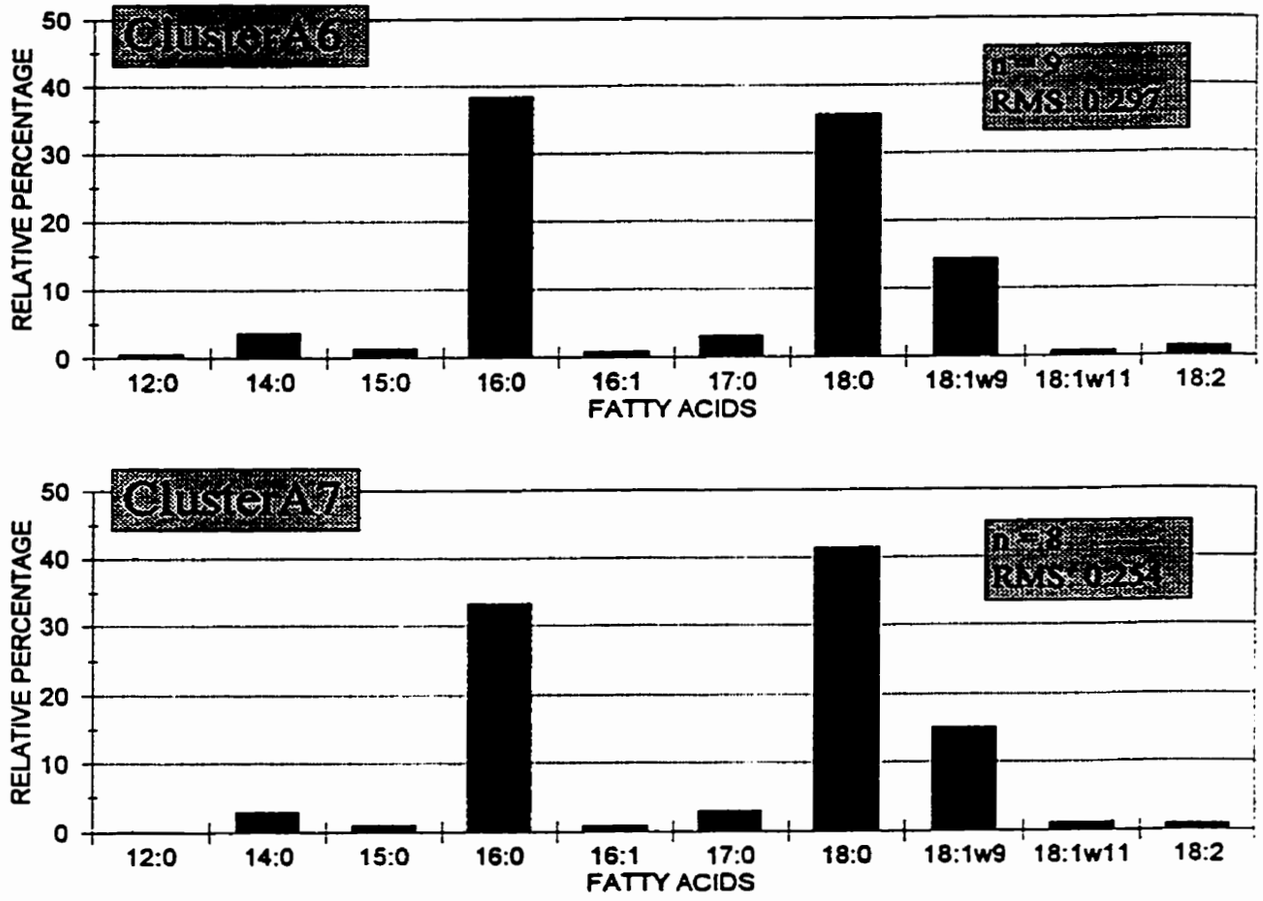


Figure G-5. Bar graph showing the average fatty acid composition of clusters A8 and A9.

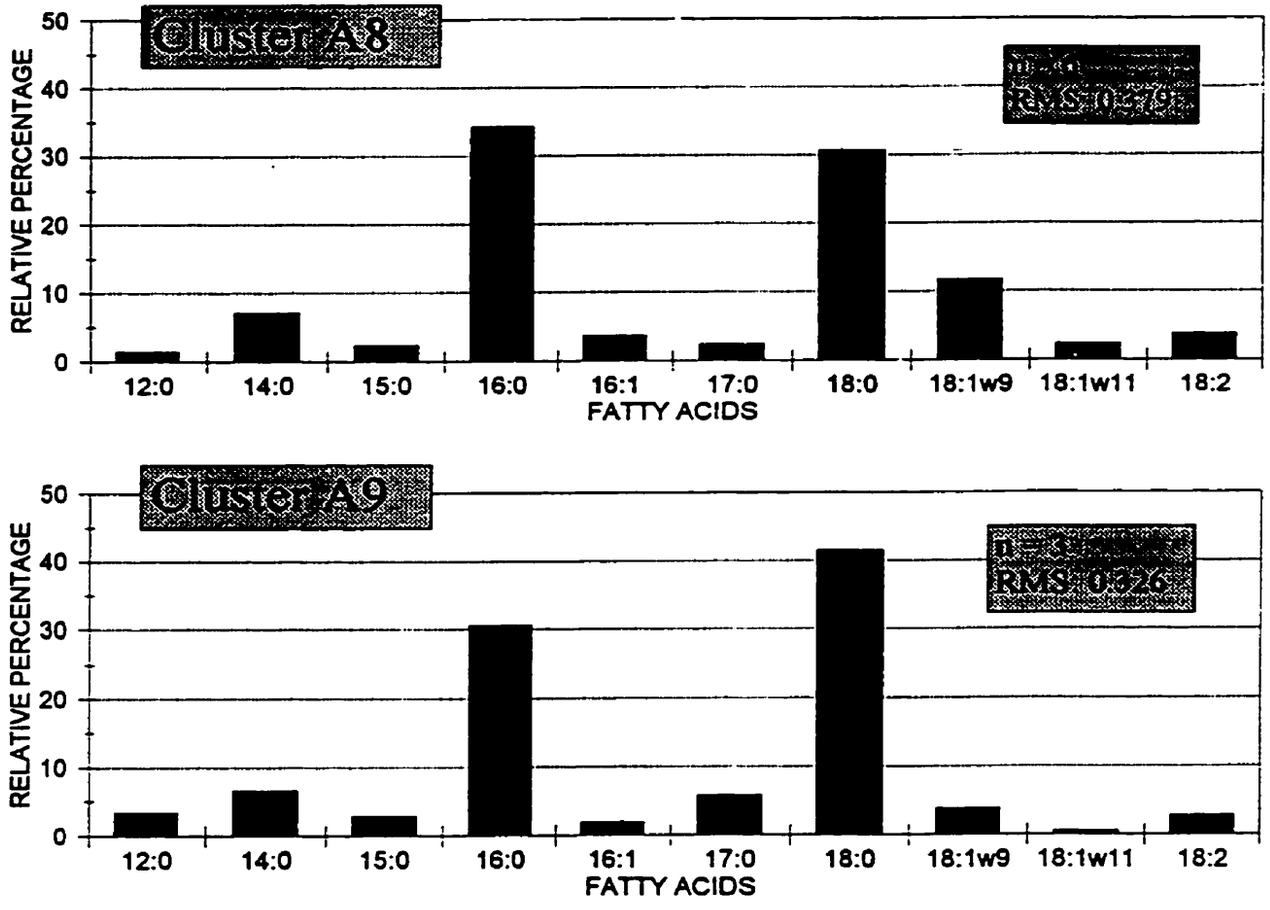


Figure G-6. Bar graph showing the average fatty acid composition of clusters A10 and A11.

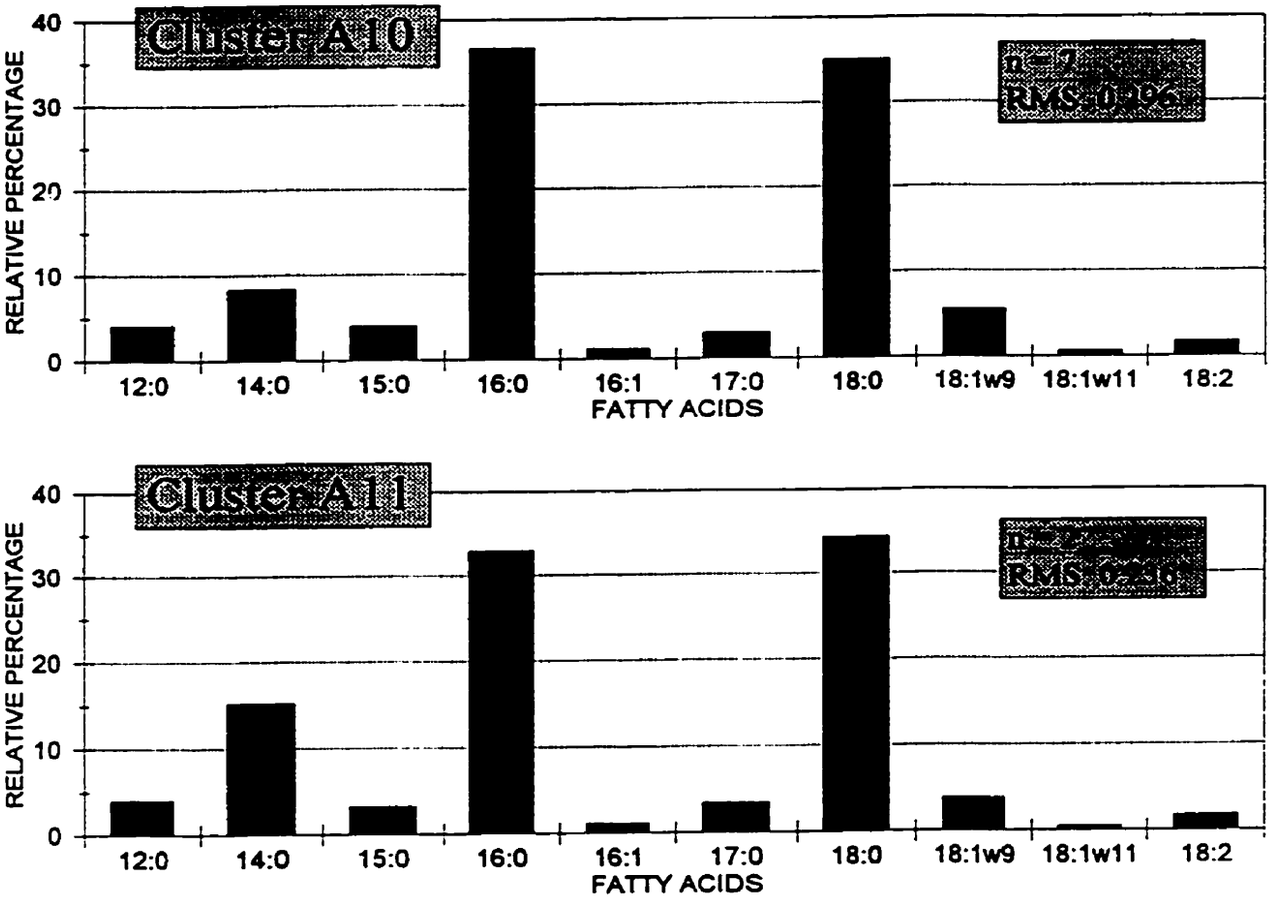


Figure G-7. Bar graph showing the average fatty acid composition of the Ross 11 residue and subcluster IV.

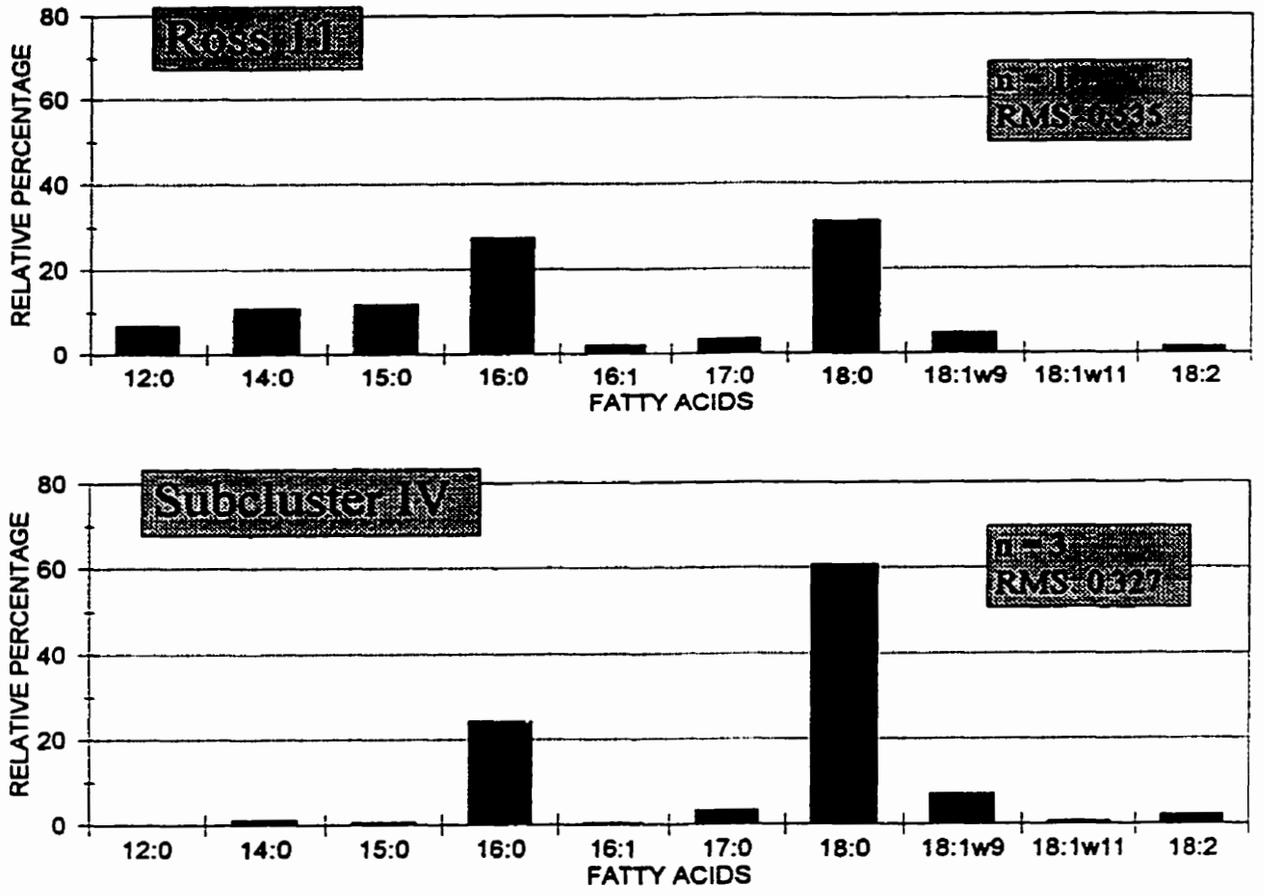


Figure G-8. Bar graph showing the average fatty acid composition of cluster B1 and the Hartley 10 residue.

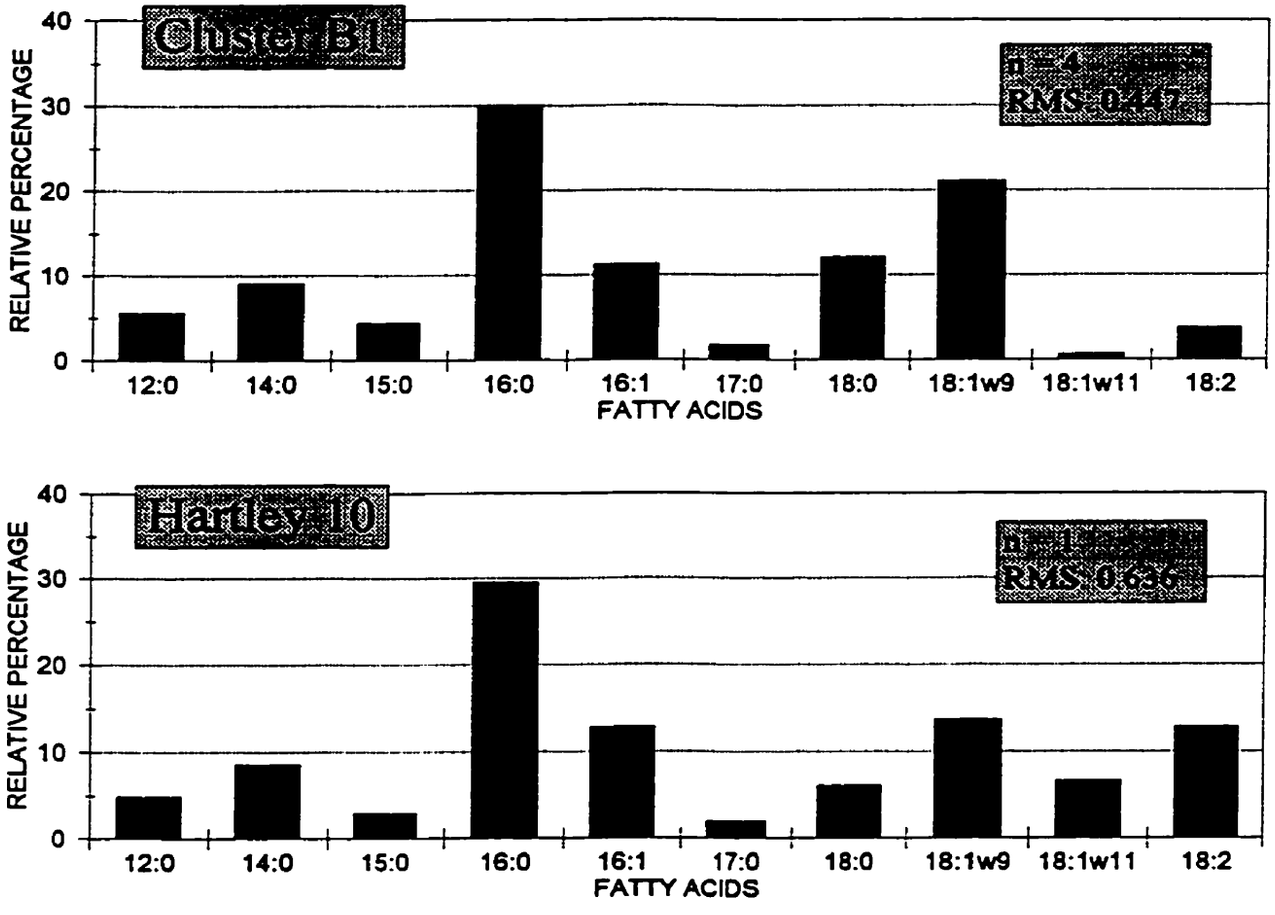


Figure G-9. Bar graph showing the average fatty acid composition of clusters B2 and B3.

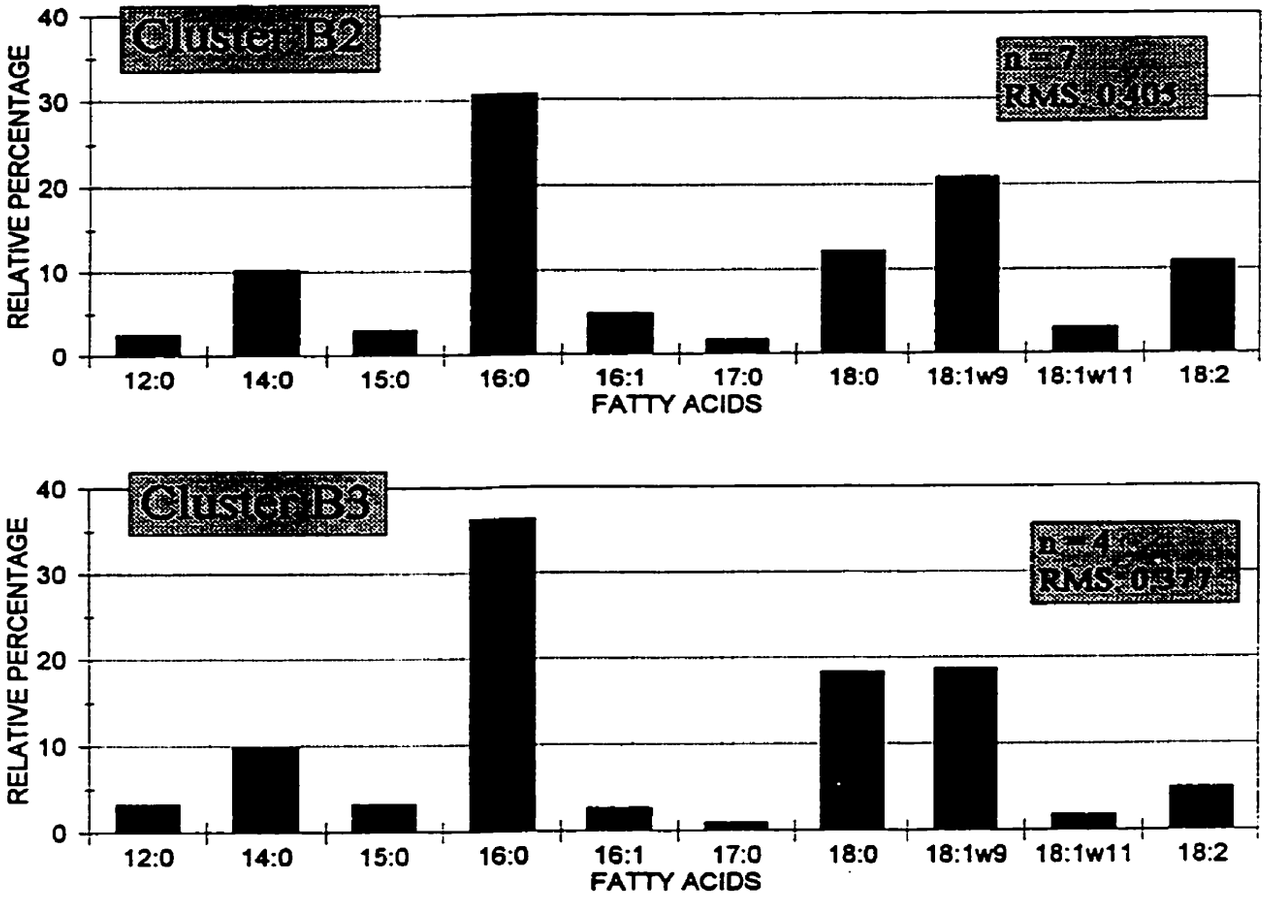


Figure G-10. Bar graph showing the average fatty acid composition of clusters B4 and the Hartley 9 residue.

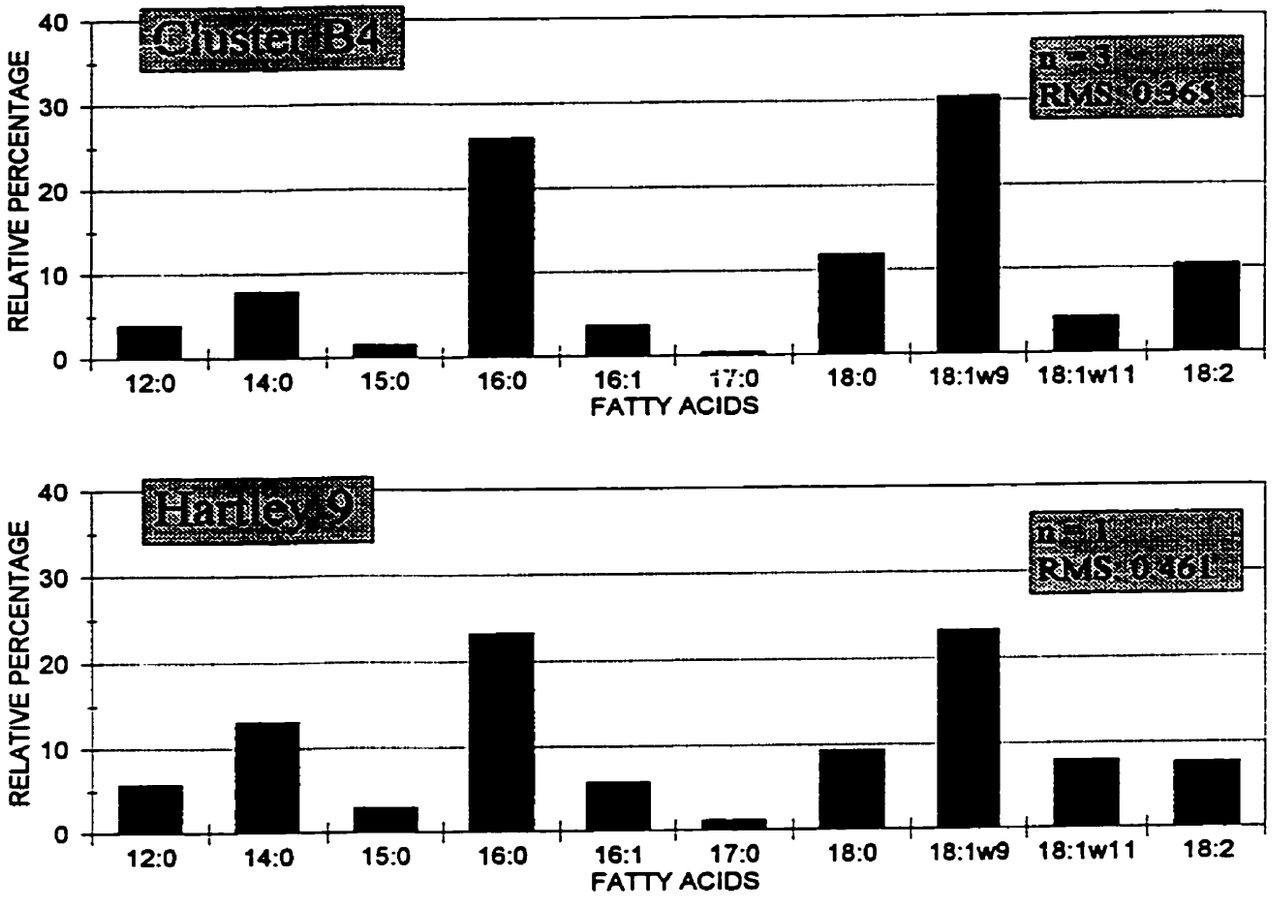


Figure G-11. Bar graph showing the average fatty acid composition of the Lebret 9 and Sjovold 4 residues.

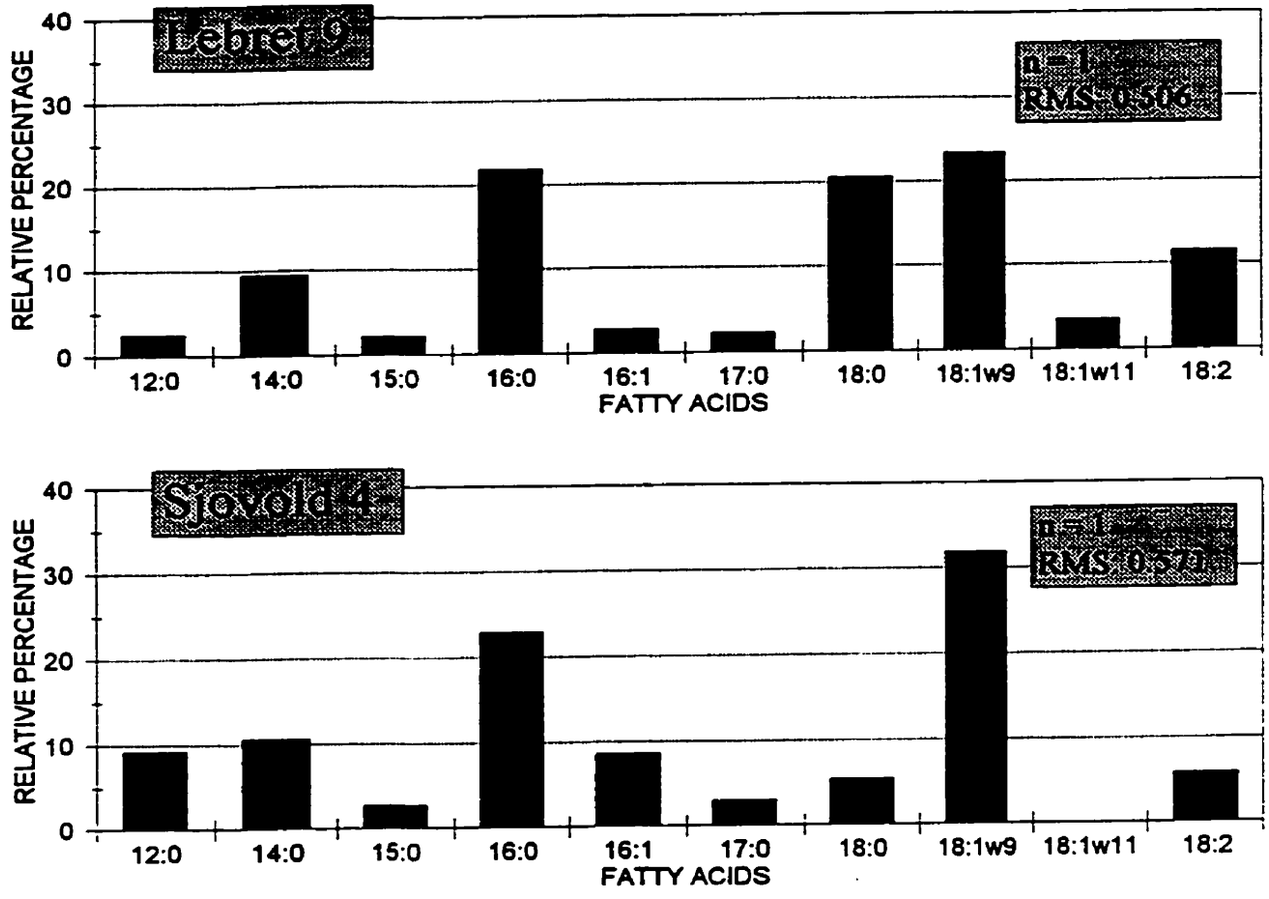


Figure G-12. Bar graph showing the average fatty acid composition of clusters B5 and B6.

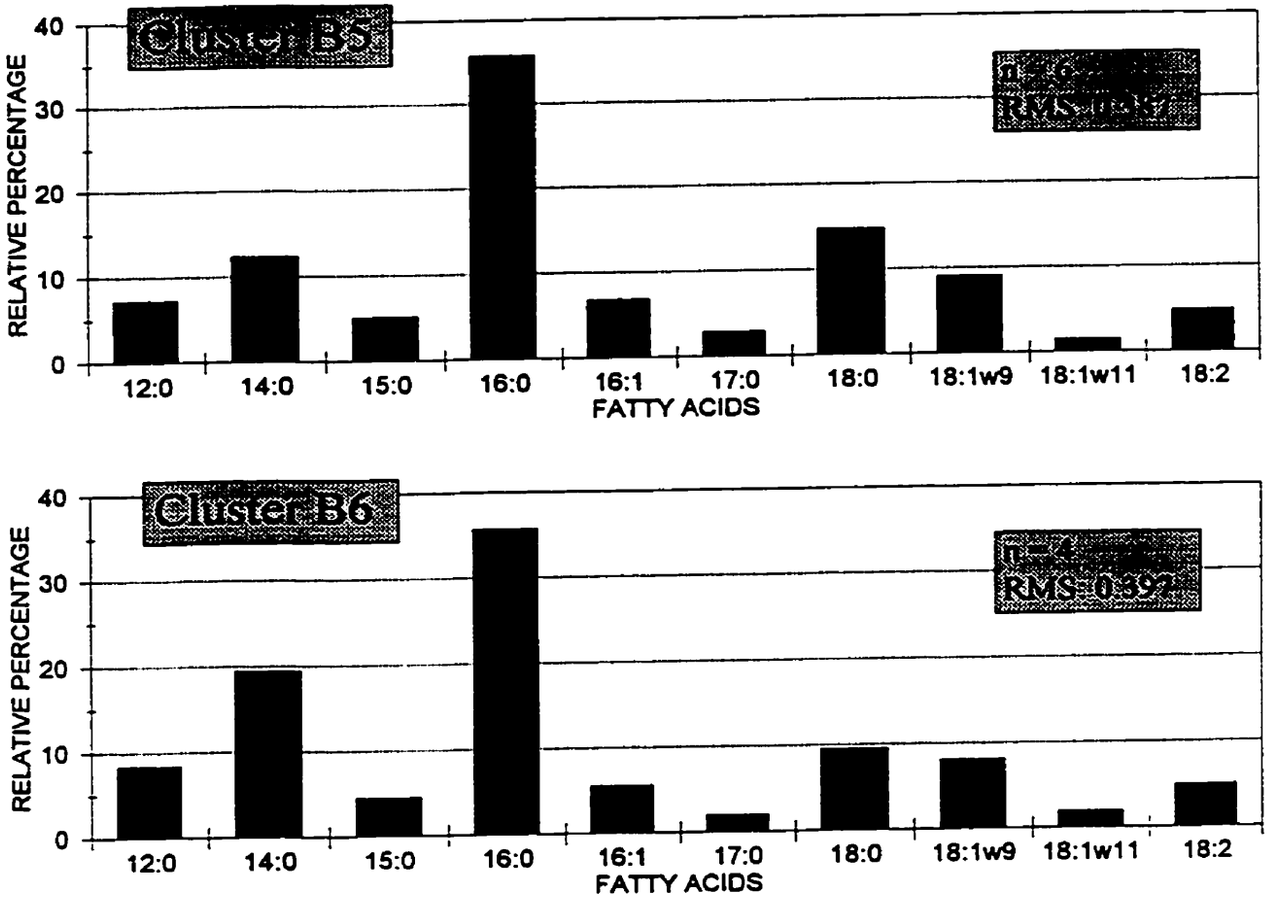


Figure G-13. Bar graph showing the average fatty acid composition of clusters B7 and B8.

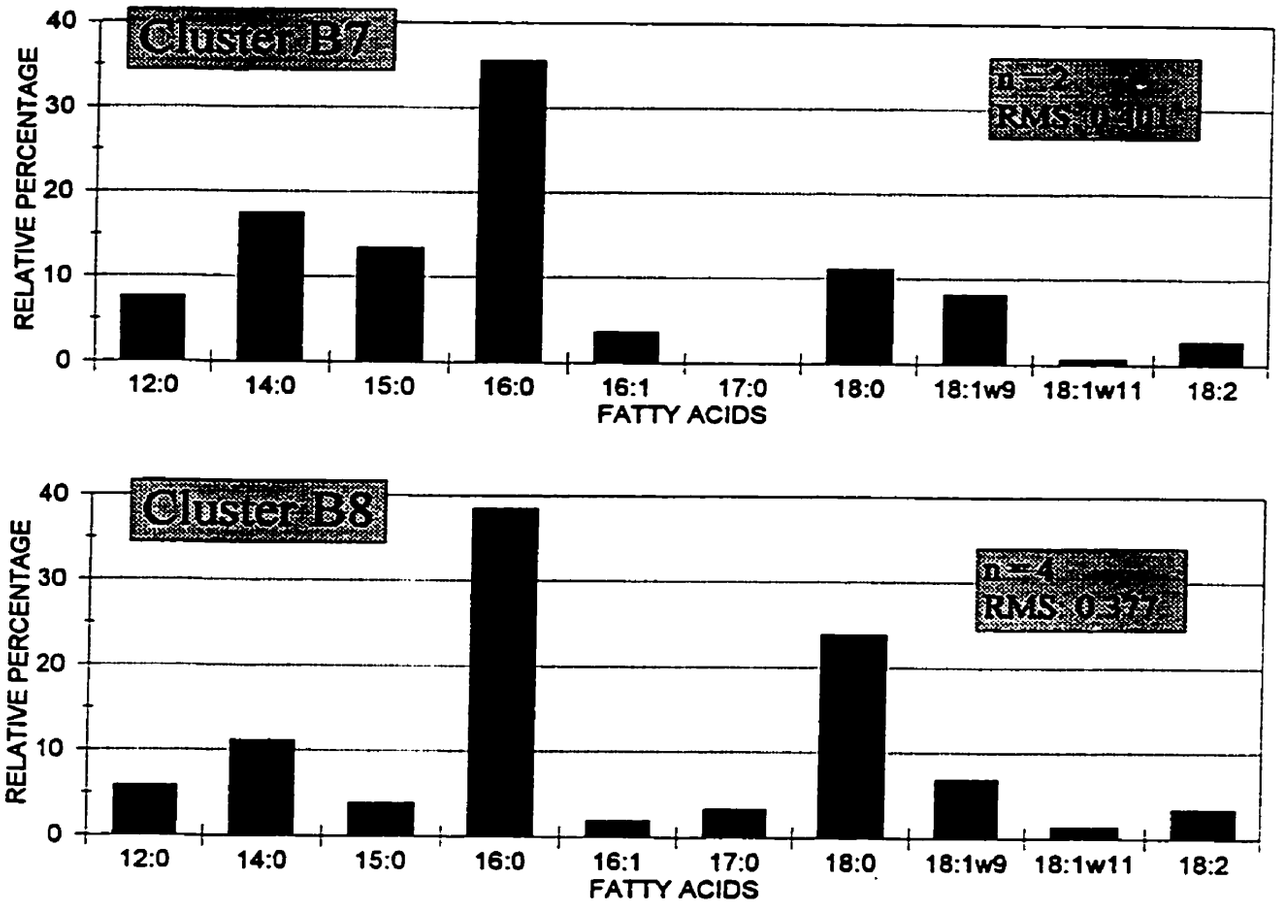


Figure G-14. Bar graph showing the average fatty acid composition of clusters B9 and B10.

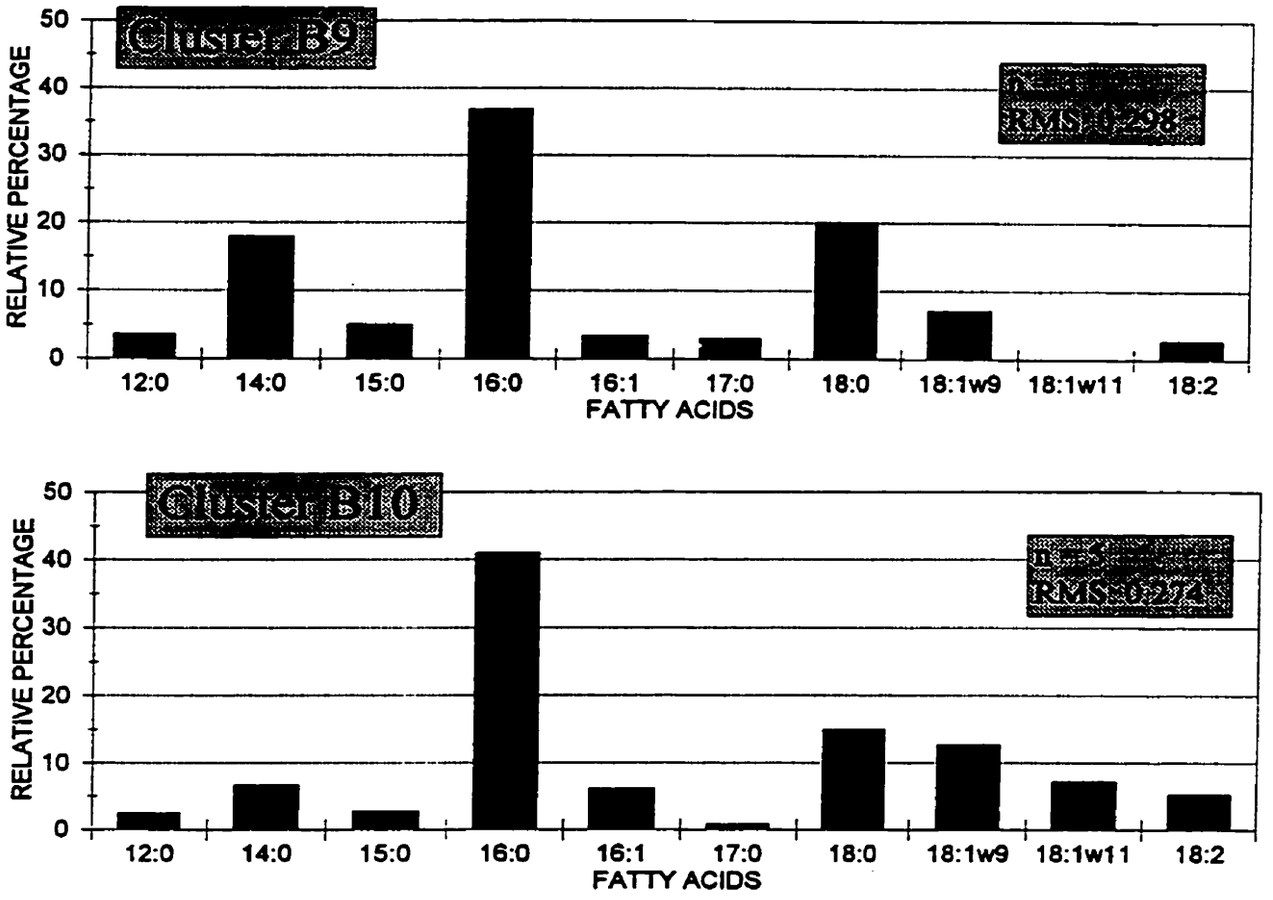


Figure G-15. Bar graph showing the average fatty acid composition of cluster B11 and the Asch 12 residue.

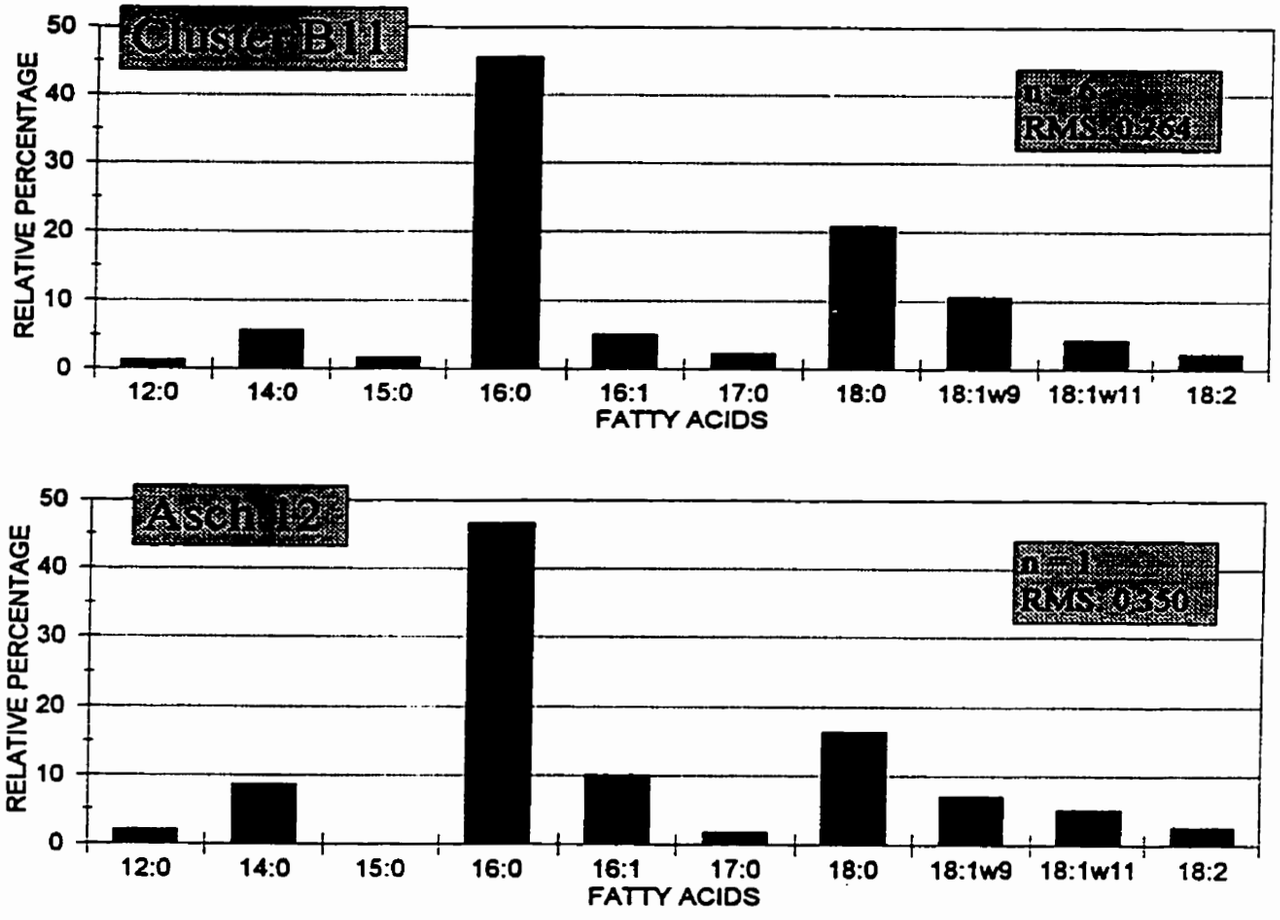


Figure G-16. Bar graph showing the average fatty acid composition of cluster B12 and the Asch 17 residue.

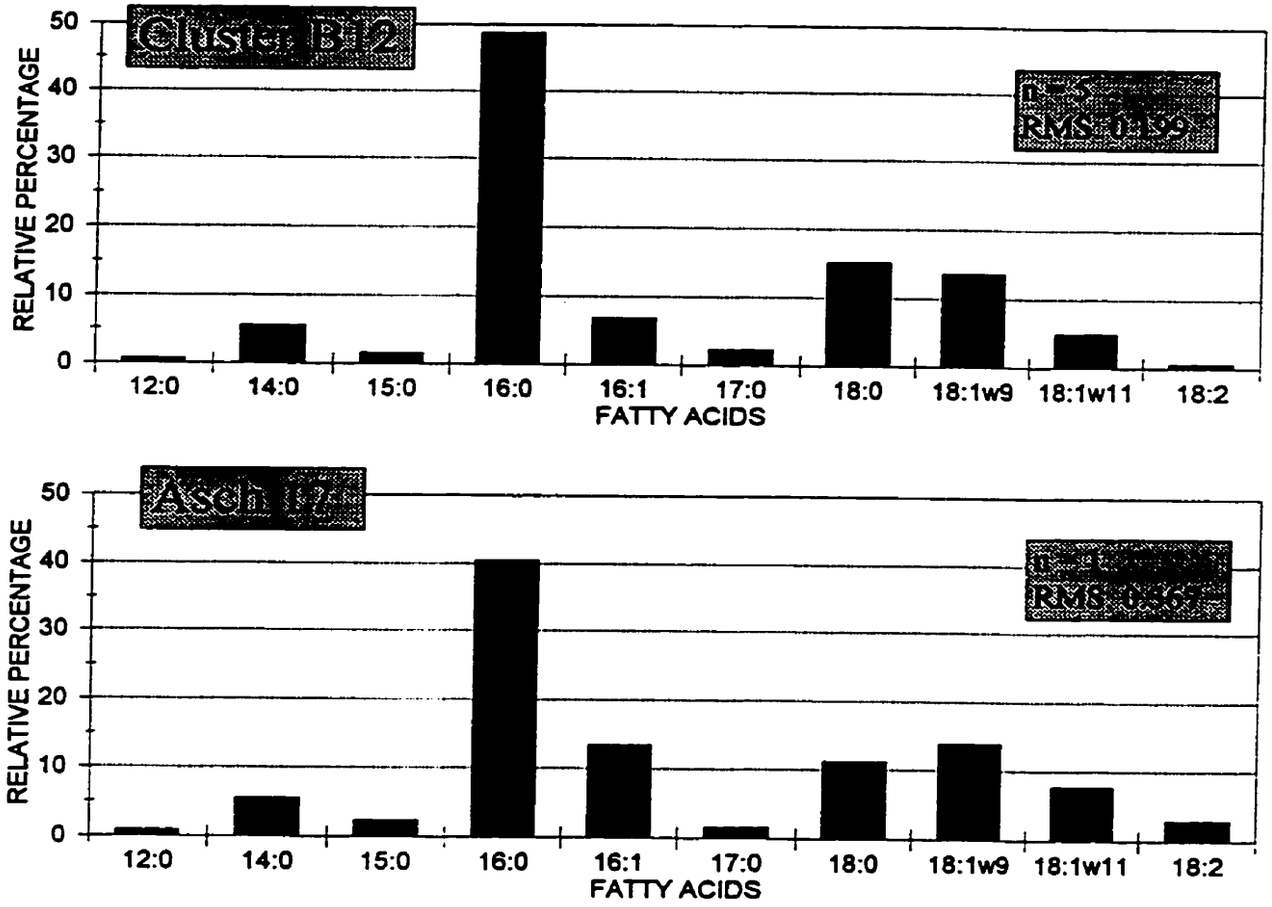


Figure G-17. Bar graph showing the average fatty acid composition of cluster B13 and the Asch 16 residue.

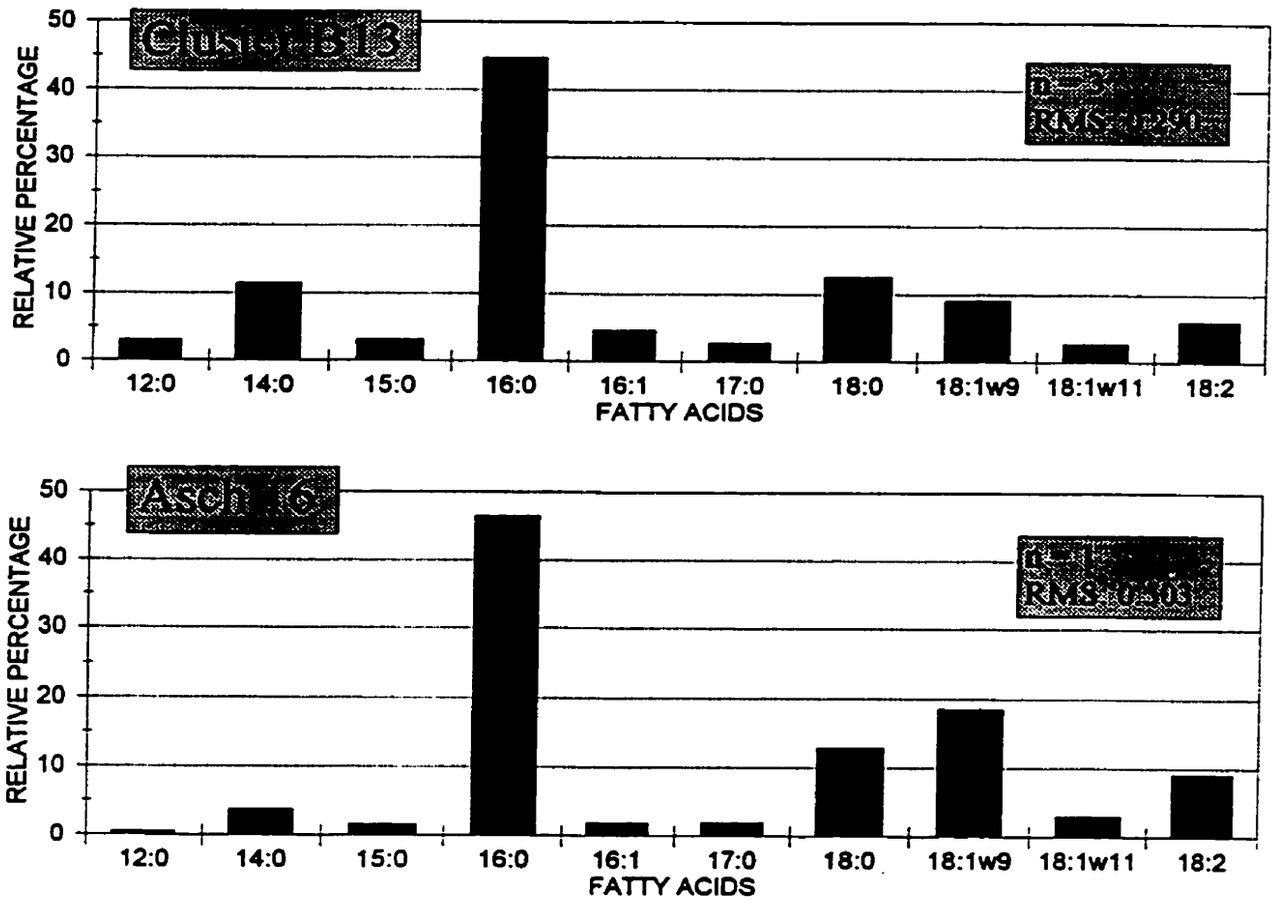


Figure G-18. Bar graph showing the average fatty acid composition of cluster B14 and the CabPt 9 residue.

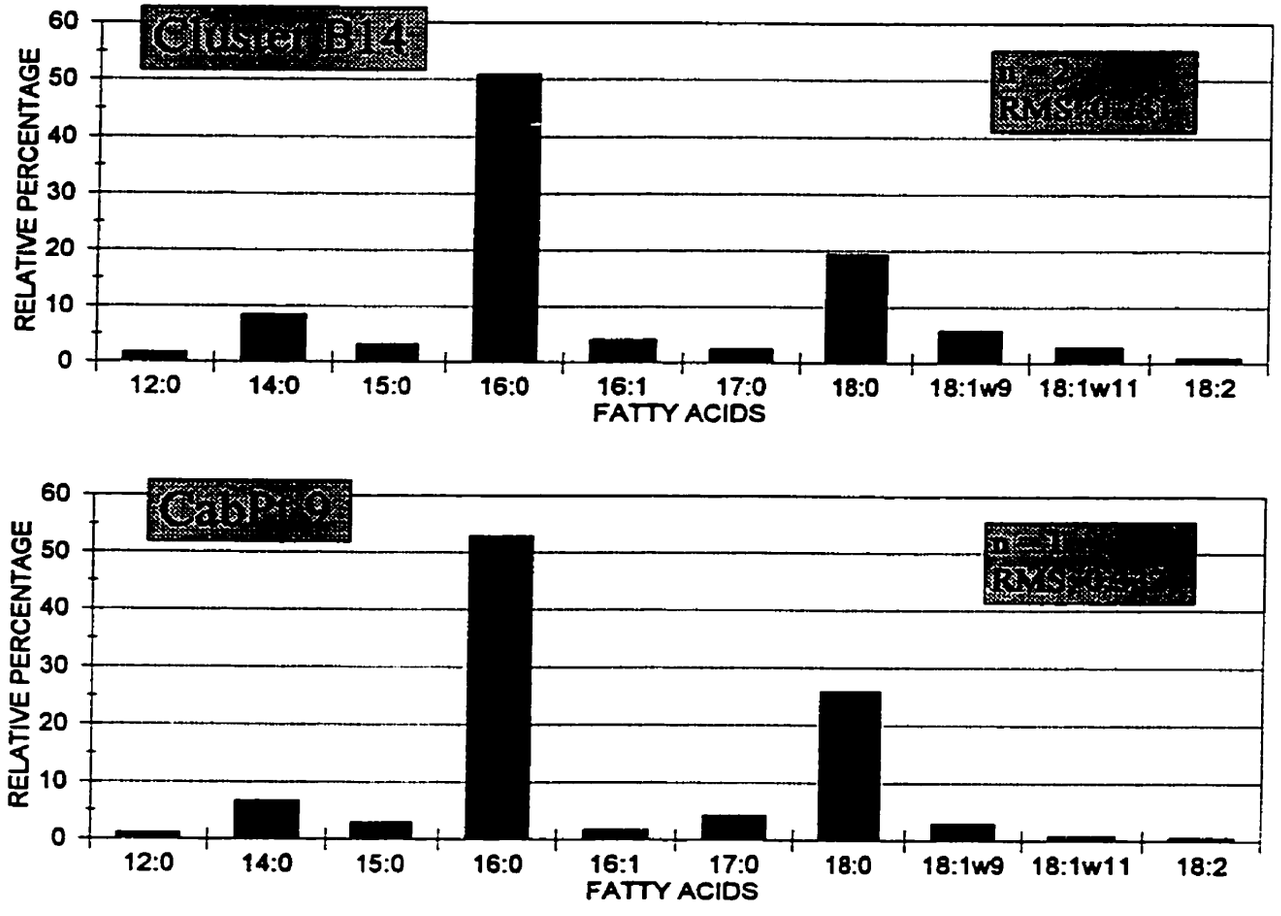


Figure G-19. Bar graph showing the average fatty acid composition of the CabPt 8 residue and Subcluster VIII.

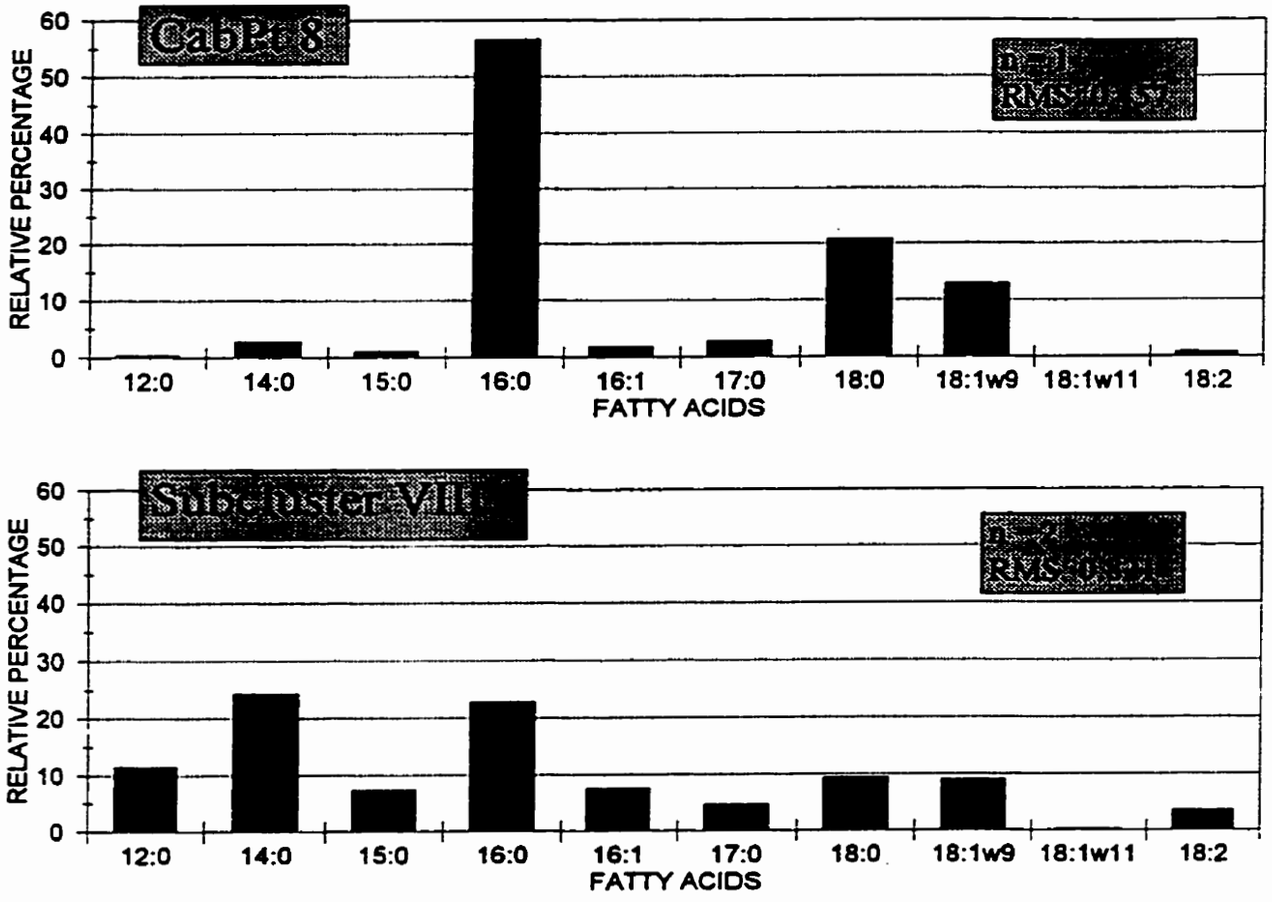
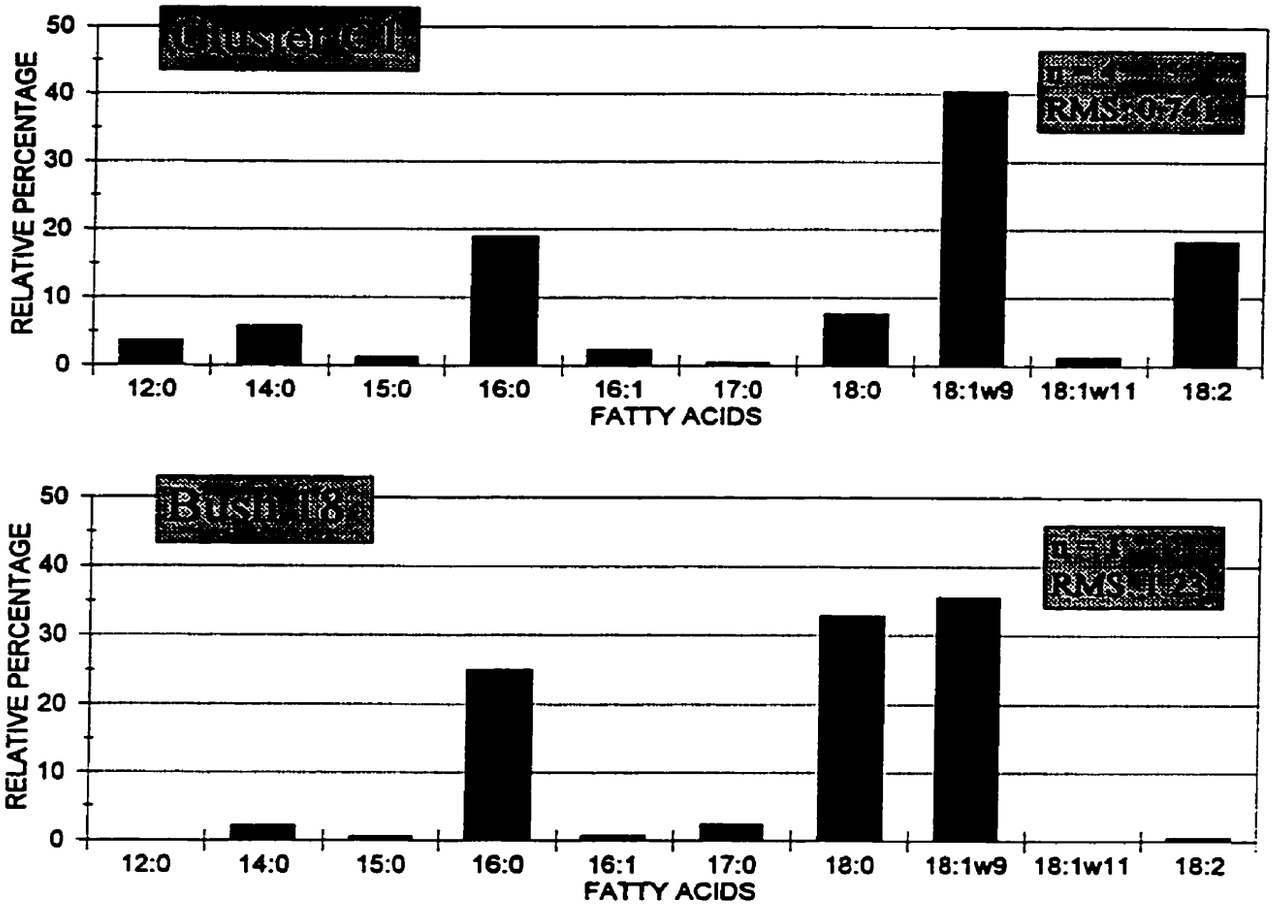


Figure G-20. Bar graph showing the average fatty acid composition of cluster C1 and the Bush 18 residue.



APPENDIX H: Residue Identifications by Site

Table H-1. Identified Residues from the Sanderson Site - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR1	Sand1a	I : A1	-1.448	-0.077	large herbivore
VR2	Sand1b	I : A2	-1.709	-0.038	large herbivore
VR3	Sand7	II : A6	-0.504	0.2841	large herb + plant or marrow
VR4	Sand10a	I : A4	-2.174	-0.324	large herbivore
VR5	Sand10b	I : A5	-1.329	-0.814	large herbivore
VR7	Sand2	II : A6	-1.218	-0.368	large herbivore
VR8	Sand3	IV : A12	-1.665	-1.031	large herbivore? C18:0 ≈ 60%
VR9	Sand4	V : B1	3.0099	-0.397	fish or corn
VR10	Sand5a	I : A4	-2.109	-0.411	large herbivore
VR11	Sand5b	V : B1	3.0094	-0.086	fish or corn with plant
VR12	Sand6a	III : A9	-0.895	1.1202	large herbivore
VR13	Sand6b	VI : B5	2.6212	0.1169	plant
VR14	Sand8	I : A2	-2.149	-0.06	large herbivore
VR15	Sand9	I : A4	-2.1	-0.238	large herbivore
VR16	Sand11	I : A2	-2.059	-0.066	large herbivore

Table H-2. Identified Residues from the Morkin Site - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR31	Mork1	III : A10	0.6411	1.3171	plant and large herbivore
VR32	Mork2	III : A10	-0.536	0.2981	large herbivore
VR33	Mork3	VI : B9	1.4697	0.995	plant
VR35	Mork5	I : A2	-1.953	0.5899	large herbivore
VR36	Mork6	I : A1	-1.802	-0.155	large herbivore

VR37	Mork7	I : A3	-1.495	0.4813	large herbivore
VR38	Mork8	I : A1	-1.352	-0.19	large herbivore
VR39	Mork9	I : A1	-1.607	-0.081	large herbivore
VR40	Mork10	I : A2	-1.719	0.184	large herbivore
VR41	Mork11	III : A9	-1.409	3.1132	large herbivore
VR42	Mork12	I : A2	-1.376	0.5506	large herbivore
VR43	Mork13	I : A2	-1.251	0.8598	large herbivore
VR44	Mork14	III : A10	0.0098	0.8802	plant and large herbivore

Table H-3. Identified Residues from the Ross Site - Grassland

Sample	**Sites**	**Cluster**	**Prin1**	**Prin2**	**Identification**
VR45	Ross1	VI : B8	2.142	3.0245	plant
VR46	Ross2	I : A2	-1.637	0.422	large herbivore
VR47	Ross3	III : A10	-0.754	1.4202	large herbivore
VR48	Ross4	III : A10	-0.176	1.7959	plant and large herbivore
VR49	Ross5	I : A2	-1.463	-0.323	large herbivore
VR50	Ross6	VI : B5	2.9716	2.8889	plant
VR51	Ross7	II : A6	-0.94	-0.476	large herbivore
VR52	Ross8	III : A10	0.3031	2.2954	plant and large herbivore
VR53	Ross9	I : A2	-1.43	0.1014	large herbivore
VR54	Ross10	I : A4	-1.967	-0.652	large herbivore
VR55	Ross13	I : A4	-1.992	0.0296	large herbivore
VR56	Ross11	+ III:A9-A11	1.7924	4.0453	plant and large herbivore
VR57	Ross12	I : A2	-2.123	0.0116	large herbivore

Table H-4. Identified Residues from Head-Smashed-In - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR136	HSI1	I : A4	-2.414	0.2554	large herbivore
VR137	HSI2	I : A4	-1.901	-0.687	large herbivore
VR138	HSI3	IV : A12	-1.841	-0.983	large herbivore? C18:0≈ 60%
VR139	HSI4	IV : A12	-2.585	-0.096	large herbivore? C18:0 ≈ 60%

Table H-5. Identified Residues from Long John Site - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR172	LngJn1	I : A2	-1.4	0.14753	large herbivore
VR173	LngJn2	I : A2	-1.77	0.06168	large herbivore
VR174	LngJn3	VI : B6	3.838	0.9447	plant
VR175	LngJn4	I : A2	-1.82	0.21542	large herbivore
VR176	LngJn5	I : A2	-1.53	-0.2163	large herbivore
VR177	LngJn6	I : A1	-1.42	-0.24631	large herbivore
VR178	LngJn7	I : A4	-1.91	-0.24437	large herbivore
VR179	LngJn8	I : A2	-1.64	0.50151	large herbivore
VR180	LngJn9	I : A1	-1.72	-0.04405	large herbivore
VR181	LngJn10	I : A3	-1.18	0.22838	large herbivore
VR182	LngJn11	I : A4	-2.49	0.64136	large herbivore
VR183	LngJn12	I : A1	-1.42	-0.33904	large herbivore
VR184	LngJn13	I : A1	-1.46	-0.17166	large herbivore
VR185	LngJn14	I : A1	-1.15	-0.37248	large herbivore

Table H-6. Identified Residues from the Sjovold site - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR186	Sjovold1	I : A2	-1.5	-0.7	large herbivore
VR187	Sjovold2	I : A5	-1.77	-0.03	large herbivore
VR188	Sjovold3	II : A6	-0.8	-0.485	large herb. + plant or marrow
VR189	Sjovold4	+ V:B1-B4	4.075	0.34	beaver

Table H-7. Identified Residues from the Garratt Site - Grassland

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR190	Garratt1	I : A4	-2.003	-0.012	large herbivore
VR191	Garratt2	II : A8	0.4257	0.7643	large herbivore (+ plant?)
VR192	Garratt3	I : A4	-1.687	-0.145	large herbivore
VR193	Garratt4	VI : B9	1.1451	2.0314	plant
VR194	Garratt5	VI : B8	1.1797	2.0824	plant
VR195	Garratt6	I : A4	-1.826	0.4649	large herbivore
VR196	Garratt7	I : A1	-1.573	0.162	large herbivore
VR197	Garratt8	I : A5	-1.74	-0.259	large herbivore
VR198	Garratt9	VI : B6	3.3355	3.0958	plant
VR199	Garratt10	VI : B6	3.3949	2.977	plant
VR200	Garratt11	III : A11	0.6442	1.4231	plant with large herbivore
VR201	Garratt12	I : A4	-2.008	0.334	large herbivore
VR202	Garratt13	I : A4	-2.109	0.1718	large herbivore

Table H-8. Identified Residues from the Lowton site - Transition Zone

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR17	Low1	I : A3	-1.56934	0.23435	large herbivore
VR18	Low2	I : A1	-2.01193	-0.1964	large herbivore
VR19	Low3	I : A3	-1.5937	0.64691	large herbivore
VR20	Low4	I : A3	-1.54181	0.31308	large herbivore
VR21	Low5	I : A2	-1.73528	0.15226	large herbivore
VR22	Low6	II : A6	-1.07919	-0.558	large herbivore
VR23	Low7	I : A4	-1.92568	0.04687	large herbivore
VR24	Low8	I : A1	-1.73853	0.17868	large herbivore
VR25	Low9	I : A2	-1.15566	0.72149	large herbivore
VR26	Low10	I : A2	-1.49503	0.74025	large herbivore
VR27	Low11	I : A2	-1.59454	0.04801	large herbivore
VR28	Low12	VI : B9	1.56057	2.08242	plant and large herbivore
VR29	Low13	I : A2	-0.92325	0.99599	large herbivore
VR30	Low14	I : A2	-1.68755	0.09984	large herbivore

Table H-9. Identified Residues from Lake Midden - Transition Zone

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR76	LkMid1	I : A2	-2.12429	0.2131	large herbivore
VR77	LkMid2	VI : B5	2.93867	1.43904	plant
VR78	LkMid3	VI : B6	3.78851	1.91413	plant
VR79	LkMid4	I : A3	-1.1828	0.87952	large herbivore
VR80	LkMid5	I : A1	-1.59289	0.4793	large herbivore
VR81	LkMid6	I : A1	-1.9762	0.29228	large herbivore
VR82	LkMid7	VIII:B15	3.66891	5.87247	plant

VR83	LkMid8	I : A1	-1.38348	0.22927	large herbivore
VR84	LkMid9	V : B3	1.93811	-1.0507	fish or corn
VR85	LkMid10	I : A2	-1.43094	0.42257	large herbivore
VR86	LkMid11	I : A3	-1.71172	0.33522	large herbivore
VR87	LkMid12	I : A1	-1.7089	0.4017	large herbivore
VR88	LkMid13	+ I:A1-A2	-2.22985	0.05052	large herbivore
VR89	LkMid14	I : A2	-2.0937	0.03133	large herbivore
VR90	LkMid15	I : A2	-1.72159	-0.2557	large herbivore
VR91	LkMid16	I : A1	-1.2463	-0.3219	large herbivore

Table H-10. Identified Residues from the Stott site - Transition Zone

Sample	**Sites**	**Cluster**	**Prin1**	**Prin2**	**Identification**
VR109	Stott1	II : A7	-0.81703	-1.2136	large herb.+ plant or marrow
VR111	Stott3	II : A7	-1.16669	-0.5177	large herbivore
VR112	Stott4	II : A8	0.56385	0.1148	large herbivore
VR113	Stott5	I : A4	-1.86101	-0.1239	large herbivore
VR114	Stott6	III : A9	-0.52677	0.32168	large herbivore
VR115	Stott7	VI : B7	4.37348	3.60268	plant
VR116	Stott8	I : A2	-1.89434	-0.4265	large herbivore
VR117	Stott9	I : A4	-1.92437	-0.5039	large herbivore
VR118	Stott10	I : A5	-1.48426	-0.7454	large herbivore
VR119	Stott11	I : A2	-1.61118	-0.5144	large herbivore
VR120	Stott12	III : A10	1.06483	1.84012	plant and large herbivore
VR121	Stott13	I : A2	-1.93485	-0.432	large herbivore
VR122	Stott14	I : A5	-1.87765	0.62026	large herbivore
VR123	Stott15	I : A2	-2.07819	-0.1505	large herbivore
VR124	Stott16	I : A5	-1.9073	-0.1617	large herbivore

Table H-11. Identified Residues from the Hartley site - Transition Zone

No.	Sites	Cluster	Prin1	Prin2	Identification
VR126	Hartley1	II : A6	-1.178	-0.699	large herbivore
VR127	Hartley2	I : A2	-1.456	-0.899	large herbivore
VR129	Hartley4	I : A1	-1.632	-0.376	large herbivore
VR130	Hartley5	I : A4	-1.947	-0.556	large herbivore
VR131	Hartley6	II : A8	0.4305	-1.469	large herb.+plant or marrow
VR132	Hartley7	II : A8	1.1568	-0.184	large herbivore
VR133	Hartley8	I : A2	-2.237	-0.075	large herbivore
VR134	Hartley9	+ V:B1-B4	4.542	-1.532	beaver
VR135	Hartley10	+ V:B1-B3	4.689	-1.458	fish or corn with plant

Table H-12. Identified Residues from the Lebret site - Transition Zone

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR160	Lebret1	VII : B13	1.6799	0.2865	plant
VR161	Lebret2	II : A8	1.2655	-1.55	large herb.+plant or marrow
VR162	Lebret3	I : A4	-2.262	-0.598	large herbivore
VR163	Lebret4	II : A8	0.1219	-0.327	large herbivore
VR164	Lebret5	VI : B8	1.6795	1.909	plant
VR165	Lebret6	V : B2	2.6872	0.743	fish or corn and plant
VR166	Lebret7	VII : B13	1.9562	1.077	plant
VR167	Lebret8	II : A6	-0.728	-0.771	large herbivore
VR168	Lebret9	V:B1-B4	2.6625	-1.684	beaver
VR169	Lebret10	V : B2	3.6833	-0.649	fish or corn and plant
VR170	Lebret11	V : B2	2.9104	-1.023	fish or corn and plant
VR171	Lebret12	VII : B11	0.4962	-0.93	fish or corn

Table H-13. Identified Residues from the Lovstrom site - Transition Zone

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR211	Lvstrm1	I : A5	-2.011	0.42353	large herbivore
VR212	Lvstrm2	I : A2	-1.977	0.29754	large herbivore
VR213	Lvstrm3	V : B2	2.4535	-0.7161	fish or corn

Table H-14. Identified Residues from the Bushfield West site - Parkland

No.	Sites	Cluster	Prin1	Prin2	Identification
VR141	Bush1	I : A4	-2.2473	0.2648	large herbivore
VR142	Bush2	II : A6	-1.1148	-0.509	large herbivore
VR143	Bush3	I : A4	-2.333	0.761	large herbivore
VR144	Bush4	II : A7	-1.0978	0.9237	large herb.+plant or marrow
VR145	Bush5	III : A11	0.0917	2.4333	plant and large herbivore
VR146	Bush6	VI : B9	0.1573	1.2736	plant and large herbivore
VR147	Bush7	II : A7	-1.2608	-0.422	large herbivore
VR147	Bush8	VI : B5	2.0842	2.7101	plant
VR149	Bush9	I : A1	-1.2082	-0.311	large herbivore
VR150	Bush10	VII : B10	1.3963	-0.709	fish or corn
VR151	Bush11	II : A7	-1.48	-0.748	large herb.+plant or marrow
VR152	Bush12	II : A6	-0.4857	-1.341	large herb.+plant or marrow
VR153	Bush13	I : A5	-1.5251	0.2471	large herbivore
VR154	Bush14	I : A2	-1.998	-0.166	large herbivore
VR155	Bush15	V : B1	3.394	0.9441	fish or corn and plant
VR156	Bush16	VIII : B15	4.9312	3.4649	plant
VR157	Bush17	VII : B10	1.1217	-0.578	fish or corn
VR158	Bush18	+ IX:C1	0.0231	-2.105	large herb.+plant or marrow
VR159	Bush19	II : A7	-1.04799	-0.789	large herb.+plant or marrow

Table H-15. Identified Residues from the Lockport West site - Parkland

No.	Sites	Cluster	Prin1	Prin2	Identification
VR203	Lckprt1	II : A7	-0.57424	-1.373	large herb.+plant or marrow
VR204	Lckprt2	VII : B11	0.79821	-1.443	fish or corn
VR205	Lckprt3	I : A2	-1.41713	-0.623	large herbivore
VR206	Lckprt4	II : A7	-1.00546	-1.013	large herbivore
VR207	Lckprt5	VII : B10	0.77543	-1.498	fish or corn
VR208	Lckprt6	VII : B10	1.27168	-1.735	fish or corn
VR209	Lckprt7	VII : B10	0.72614	-1.22	fish or corn
VR210	Lckprt8	I : A3	-0.62419	-0.805	large herbivore

Table H-16. Identified Residues from the Aschkibokahn site - Forest

Sample	Sites	Cluster	Prin1	Prin2	Identification
VR58	Asch1	VII : B12	1.664	-1.5395	fish or corn
VR59	Asch2	V : B4	3.321	-3.3274	beaver
VR60	Asch3	VII : B12	2.548	-1.6903	fish or corn
VR61	Asch4	VII : B11	0.421	-0.6663	fish or corn
VR62	Asch5	VII : B11	0.838	-0.8819	fish or corn
VR63	Asch6	VII : B11	1.032	-0.7136	plant
VR64	Asch7	V : B2	3.689	-1.9853	fish or corn
VR65	Asch8	VII : B14	0.125	-0.0034	plant
VR66	Asch9	VII : B14	1.041	0.86488	plant
VR67	Asch10	VII : B12	3.343	-2.1984	fish or corn
VR68	Asch11	VII : B12	2.721	-1.8934	fish or corn
VR69	Asch12	+VII:B10-B11	1.719	-1.0176	plant
VR70	Asch13	VII : B11	1.274	-0.773	fish or corn OR plant

VR71	Asch14	V : B3	4.26	-2.6912	beaver
VR72	Asch15	VII : B12	2.605	-1.0019	fish or corn
VR73	Asch16	+ VII : B13	1.175	-1.9377	fish or corn
VR74	Asch17	+ VII : B12	2.985	-1.896	fish or corn
VR75	Asch18	V : B2	2.718	-2.6899	fish or corn

Table H-17. Identified Residues from the Cabin Point site - Forest

Sample	**Sites**	**Cluster**	**Prin1**	**Prin2**	**Identification**
VR92	CabPt1	IX : C1	3.613	-1.4342	beaver
VR93	CabPt2	VII:B13	1.78	-0.2819	plant
VR94	CabPt3	IX : C1	4.55	-4.1692	beaver C18:2=25-30%
VR95	CabPt4	IX : C1	4.733	-5.1991	beaver C18:2=25-30%
VR96	CabPt5	V : B3	2.265	-1.0884	fish or corn and plant
VR97	CabPt6	V : B4	3.277	-1.7702	beaver
VR98	CabPt7	V : B2	3.527	-2.2174	fish or corn
VR99	CabPt8	+ VII : B14	-0.91	-0.4055	large herbivore?
VR100	CabPt9	+ VII : B14	-1.02	1.15099	large herbivore
VR102	CabPt11	IX : C1	3.843	-3.0191	beaver
VR104	CabPt13	VI : B5	2.831	0.89707	plant
VR105	CabPt14	VI : B7	4.416	4.29394	plant
VR106	CabPt15	V : B1	4.662	1.39784	fish or corn with plant
VR107	CabPt16	V : B3	3.113	0.4988	fish or corn with plant
VR108	CabPt17	V : B3	1.02	0.02425	fish or corn

Table H-18. Identified Residues from the Black Fox Island site - Forest

Sample	**Sites**	**Cluster**	**Prin1**	**Prin2**	**Identification**
VR140	BFI1	VI : B5	3.106	2.74783	plant